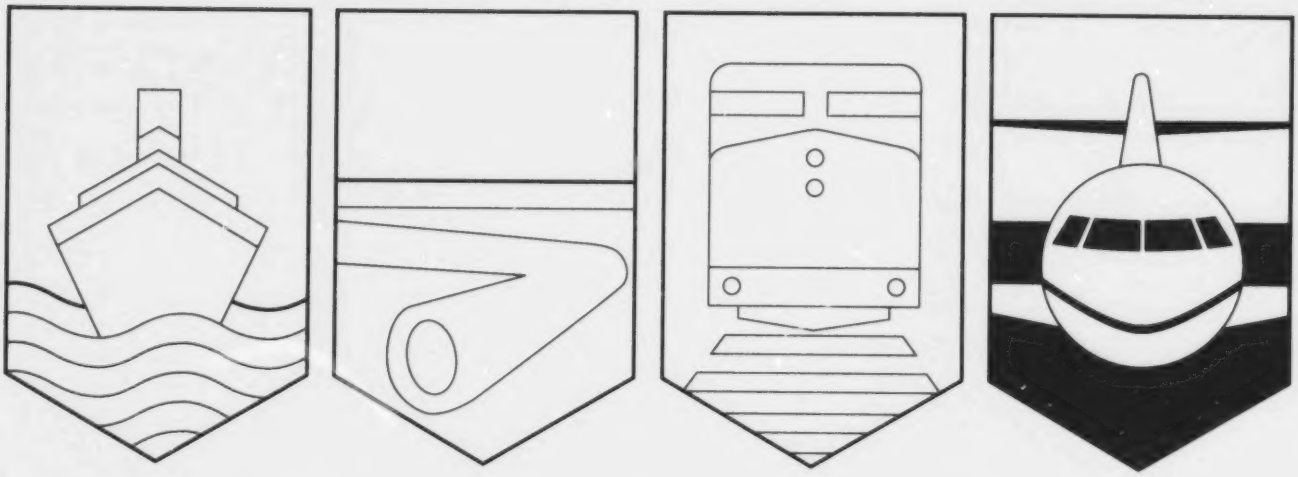
Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada



AVIATION OCCURRENCE REPORT

SKYLINK AIRLINES LTD.
FAIRCHILD AIRCRAFT CORPORATION
SA227 METRO III C-GSLB
TERRACE AIRPORT, BRITISH COLUMBIA
26 SEPTEMBER 1989

REPORT NUMBER 89H0007

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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SYNOPSIS

The aircraft, a Fairchild Metro III, was on a scheduled flight from Vancouver to Terrace, British Columbia with two pilots and five passengers on board. The aircraft crashed one quarter mile to the west of Terrace Airport while the crew was attempting to carry out a missed approach in IFR conditions. The aircraft was destroyed by the impact and a post-crash fire. All seven occupants were fatally injured in the crash.

The Transportation Safety Board of Canada (TSB) determined that the crew continued with the approach beyond the missed approach point without establishing the required visual references. The evidence indicates that, while subsequently carrying out a missed approach in IFR conditions, the aircraft was flown into the ground in a manner consistent with disorientation. Contributing to the occurrence were the inadequacy of the company's operating procedures, reduced operating standards, and the inadequate definition of the visual references required for a circling approach.

11 December 1990

Ce rapport est également disponible en français.

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1.0 FACTUAL INFORMATION

1.1 History of the Flight

On 26 September 1989, Skylink Flight 070, C-GSLB, a Fairchild Metro III, took off from Vancouver, British Columbia at 0651 Pacific daylight time (PDT)* on a scheduled domestic flight to Terrace, British Columbia. The aircraft carried two crew, five passengers, and a quantity of cargo. The flight was scheduled to take off at 0630 PDT; however, when taxiing out for take-off, the aircraft returned part way to the ramp for an undetermined reason and then returned to the take-off position. This resulted in a 21-minute delay in the departure time.

The centre-stored flight plan called for the flight to proceed from Vancouver to the 312-degree radial of the Vancouver very high frequency omni-directional range (VOR)** at 100 nautical miles*** and then direct to the KITIMAT non-directional beacon (NDB) at flight level (FL) 180. This en-route portion of the flight from Vancouver to the Kitimat NDB was completed at FL200.

At 0811 PDT, the crew of Flight 070 requested and received descent clearance to 15,000 feet from Vancouver Centre. At 0818 PDT, Flight 070 was cleared to hold at the KITIMAT NDB because a Lear Jet, C-GWFG, had missed the approach at Terrace and had been issued a clearance for a second approach. However, shortly thereafter, at 0820 PDT, the Lear Jet landed on runway 15 without having to carry out this approach, and Flight 070 was cleared for an approach at Terrace.

The crew elected to fly the localizer type directional aid/distance measuring equipment C (LDA/DME C) approach to the airport (Appendix B). After receiving a description of the weather at the airport from the flight service station (FSS) specialist as well as a pilot report on the local weather conditions from the pilot of the Lear Jet, the crew decided to conduct a circling approach for a landing on runway 15.

* All times are PDT (Coordinated Universal Time (UTC) minus seven hours) unless otherwise stated.
** See Glossary for all abbreviations and acronyms.
*** Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

At 0821 PDT, the aircraft crossed the KITIMAT NDB inbound and commenced the descent for the approach. During the descent, at 0824 PDT, and at an altitude of 6,800 feet, the landing gear was selected down and the flaps were selected to one half. At 0825 PDT, the aircraft crossed the TERRACE NDB at an altitude of 3,050 feet and began descending to minimum descent altitude (MDA). During the descent to the TERRACE NDB, the airspeed was decreased from 240 knots at the start of the descent to 170 knots at the NDB. Fifty-three seconds after crossing the TERRACE NDB and at an altitude of 1,650 feet above sea level (asl), the crew reported visual contact with the ground. At 0827 PDT, at an altitude of 1,200 feet asl and just prior to reaching the published missed approach point (MAP), the captain stated "OK, I got the button here." Fourteen seconds after this, the captain saw the button of runway 27. At approximately this same time, the aircraft was observed on what corresponded to a downwind leg for runway 15 at about 500 feet above ground level (agl), flying straight and level over the threshold of runway 27, with the landing gear down. The aircraft crossed the localizer transmitter at an altitude of 1,100 feet asl and at an airspeed of 140 knots.

Approximately 30 seconds after crossing the localizer transmitter (Appendix A), the aircraft commenced a descent out of 1,100 feet, and the flaps were lowered to the full position. The aircraft then levelled at an altitude of approximately 900 feet. At or about this same time, the aircraft was observed on base leg for runway 15 at a low altitude, close to the east/west ridge located about 1.5 miles north of the airport.

While on final approach to runway 15, the aircraft engines were clearly heard by witnesses on the ground, but the aircraft was not visible because of the cloud and fog; however, witnesses indicated that the aircraft sounded very low and was possibly as much as 0.5 miles west of the extended centre line of runway 15.

Twenty-six seconds after full flap was selected, a missed approach was initiated, and the landing gear and flaps were selected up. Within five seconds of the initiation of the missed approach, the aircraft began to accelerate and a rate of climb of approximately 1,200 feet per minute was established. This rate of climb quickly diminished to zero, followed by the start of a descent which quickly increased to 3,000 feet per minute. As the aircraft descended, the co-pilot called "descending" twice. A few seconds later, the aircraft struck trees on the west side of runway 15 just inside the airport perimeter.

Witnesses stated that the sound of the engines was steady until the impact was heard. A second and final impact with the ground occurred just outside the airport perimeter approximately 800 feet from the initial tree strike. A fire erupted following the ground impact. There were no survivors.

The accident occurred at 0829 PDT during the hours of daylight, at lat 54°28'N, long 128°35'W, at an elevation of 713 feet asl.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	2	5	-	7
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	2	5	-	7

1.3 Damage to Aircraft

The aircraft was destroyed by the impact and the post-crash fire.

1.4 Other Damage

Two low voltage hydro cables located on the west side of Beam Station Road were broken by the aircraft just prior to ground impact.

1.5 Personnel Information

1.5.1 General

	Pilot-In-Command	Co-Pilot
Age	33	28
Pilot Licence	Airline Transport	Commercial
Medical Expiry Date	01/03/90	01/03/90
Total Flying Time	2,981 hr*	1,298 hr
Total on Type	659 hr	240 hr
Total Last 90 Days	291 hr	302 hr
Total on Type Last 90 Days	291 hr	239 hr
Hours on Duty Prior to Occurrence	3 hr	3 hr
Hours off Duty Prior to Work Period	9 hr	9 hr

* The captain's log book was not recovered, and his flying times have been estimated using the company's Record of Flying, the co-pilot's log book, flight logs, and Transport Canada (TC) records.

The captain was qualified and certified for the flight. He had completed a pilot proficiency check (PPC) on 31 January 1989, and he held a Class I Group I Instrument Rating. The captain's Licence Validation Certificate was valid with a requirement to wear glasses.

The co-pilot was qualified and certified for the flight. He had completed a PPC on 12 July 1989, and he held a Class II Group I Instrument Rating. The co-pilot's Licence Validation Certificate was valid with a requirement to wear glasses.

The captain and co-pilot had flown into Terrace on numerous occasions. They had been flying as a Metro III crew since July 1989, and all the Metro III flying during the period up to 24 September 1989 had been on the company's only other Metro III aircraft, C-GSLA. As a crew, they had accumulated a total of 16.3 hours on the accident aircraft in the two days preceding the accident and on the day of the accident. Witnesses indicated that both the captain and the co-pilot were wearing their glasses when the aircraft left the terminal in Vancouver.

1.5.2 Captain's History

The captain began his employment with Skylink Airlines in March 1988 as a co-pilot on the Metro II. He was upgraded to captain approximately 10 months later, and, in January 1989, he began performing the duties of captain on the Metro III. Prior to joining Skylink Airlines, he was employed as a captain on Piper Navajo and Britten-Norman Islander aircraft.

A review of the previous check-rides flown indicated that the captain was a competent pilot. Only minor debriefing points were noted on these rides.

The captain had been flying continuously throughout 1989 with an average flying time of 92.5 hours per month for the first six months. In July, he flew 106.8 hours and in August, 117 hours. In September, he had flown 67.5 hours up to the time of the accident.

During the week prior to the accident from 19 to 21 September, the captain took part in a hiking trip with his brother. By the brother's account, this was a strenuous trip which left them both tired. On Friday 22 September, the captain spoke to his wife, who was

away visiting her parents in Nevada, and on Saturday, 23 September, he met with his brother. Neither his wife nor his brother noted anything unusual in the captain's behaviour.

The captain and the co-pilot flew together on Sunday 24 September and Monday 25 September. On arrival back in Vancouver at 2010 PDT on the night of the 25th, the captain was described as exhausted by a company technician. In addition, he declined an invitation to join his co-workers for a coffee at a local restaurant, stating that he was tired and that he had a long day ahead of him. The company Operations Manager stated that he spoke with the captain on the morning of the accident around 0600 PDT and that the captain appeared to be in good spirits.

Although it could not be definitely determined, it is likely that the captain left the airport at about 2100 PDT after his flight on the 25th, and, assuming that he went straight home, he would have arrived there around 2200 PDT. It was determined that he attended a pre-flight briefing at 0545 PDT on the morning of the accident. He would have left home at about 0445 PDT in order to arrive at the airport at 0545 PDT, so that it is likely that he got up at 0415 PDT. Based on this schedule, he could have had a maximum of just over six hours rest.

1.5.3 Co-Pilot's History

In May 1989, the co-pilot commenced his employment with Skylink Airlines as a co-pilot on the Metro II and, in July 1989, was upgraded to the Metro III. He was formerly employed in Winnipeg where he flew as a co-pilot on the Metro II.

The co-pilot had experienced difficulties during his previous PPC ride. The report for his PPC on 12 July 1989 indicated that he had passed the ride but had experienced some problems with aircraft control. The TC inspector who performed the PPC stated that, although the co-pilot had some difficulties, he was not unsafe. PPCs previous to this were satisfactory with minor debriefing points.

The co-pilot had flown an average of 82.5 hours per month for the first six months of 1989. He flew 79.2 hours in July, 116.2 hours in August, and 102.9 hours in September prior to the accident flight.

On Saturday, 23 September, the co-pilot went out for the evening with his roommate. The roommate stated that the co-pilot had one beer and that they returned

home sometime after 2230, at which time, the co-pilot went to bed. On the evenings of 24 and 25 September, the co-pilot and his roommate went out for coffee, returning home by 2300; on both evenings, the roommate stated that the co-pilot went to bed shortly after returning home.

1.5.4 Crew Personality Profiles

The captain was friendly, well liked, and respected by his associates. He was regarded as a good, conscientious pilot by both his supervisors and his peers. He enjoyed flying and aspired to a career with a major airline. His sleep patterns were normal, and it appears that he was happily married and under no financial pressure.

The co-pilot was well liked and appeared to be happy to be crewed with the captain. Most of his time and income were utilized toward his goal of moving up in the aviation industry. He seldom drank, and, if he did, he usually had only one drink. His sleeping patterns were normal. He did not appear to have any significant outside stressors.

1.6 Aircraft Information

1.6.1 General

Manufacturer	Fairchild Aircraft Corp.
Type	Metro III SA227
Year of Manufacture	1981
Serial Number	481
Certificate of Airworthiness	Valid
Total Airframe Time	11,177 hr
Engine Type (2)	Garrett TPE 331-11U-611G
Propeller Type (2)	Dowty Rotol R321/4-82-F/8
Maximum Allowable Take-off Weight	14,500 lb
Recommended Fuel Types	Jet A-1, A-2

1.6.2 Weight and Balance

Determination of the aircraft weight and balance was complicated for three reasons. First, the aircraft weight sheet, left at Skylink in Vancouver, reflected an error in the baggage/freight section. The freight manifest supplied by the customer indicated a total freight weight of 759 pounds which combined with a baggage weight of 133 pounds, recorded on the aircraft weight sheet, totalled 892 pounds rather than the 739 pounds signed for by the captain. It could not be determined why this discrepancy of 153 pounds existed.

Second, there were no passenger seating locations available either from witnesses or from paperwork left by the crew. No centre of gravity (C of G) calculations were left in Vancouver by the crew. This was consistent with the Skylink practice of retaining this documentation on board the aircraft.

Third, no one, other than the pilots, observed the complete aircraft loading in Vancouver; however, during interviews, it was determined that, if normal company practice had been followed, most of the baggage and freight would have likely been put in the aft baggage area and that it was common for passengers to sit in the aft portion of the cabin. Examination of the wreckage indicated that two mail bags estimated at 200 pounds total were in the forward baggage area. Finally, the best information available was that the aircraft was in the 17-seat configuration.

The following assumptions were therefore used to calculate the weight and balance at the time of the accident: the five passengers were distributed evenly from front to rear throughout the cabin; 692 pounds of baggage and freight were in the aft baggage area and 200 pounds in the forward baggage area; the aircraft used 1,000 pounds of fuel en route; and five gallons of alcohol and water injection fluid were on board.

Calculations based on the above assumptions indicate that the aircraft was within weight and C of G limits throughout the flight. If the passengers were grouped in the aft seats rather than distributed evenly throughout the cabin, then it is possible that the C of G could have been at or beyond the aft limit throughout the flight. Notwithstanding the foregoing, it is not possible to definitively state where the C of G was during the flight.

1.6.3 Aircraft Records

The aircraft had been imported into Canada from the Federal Republic of Germany (FRG) on 09 September 1989 in accordance with the requirements of a technical agreement between Canada and the FRG dated 24 April 1987. All requirements of this agreement had been complied with, and a Certificate of Registration was issued on 15 September 1989 and a Certificate of Airworthiness (C of A) on 21 September 1989.

The aircraft records indicate that all applicable Airworthiness Directives (AD) had been incorporated and that the engines and propellers were serviceable and all mandatory modifications had been carried out. The only work that had been performed in Canada since the

aircraft's arrival from the FRG was essentially that which was required by TC for registration and certification plus the repainting of the aircraft. The aircraft was certified in accordance with existing regulations and procedures.

There were two aircraft defects dated 23 September 1989 which had not been rectified. The first involved the aircraft public address (PA) system, and this defect had been deferred by the radio shop. Specifically, the PA was unserviceable on the right side; however, passengers could be addressed by using the left-side speakers. The second defect concerned a bottle in the aircraft oxygen system which could not be fully topped up. The associated work order indicated that a hose was required to repair an oxygen leak; however, there was no record that the hose had been replaced. This defect was also deferred, and the passenger load was adjusted to remain in compliance with Air Navigation Order (ANO) Series II No.9, Oxygen Equipment Order.

1.6.4 Attitude Reference Systems

The other Skylink Metro III aircraft, C-GSLA, was equipped with a basic attitude indicator (AI) for pilot attitude reference whereas the accident Metro III was equipped with a more complex flight director (FD) system. Neither the crew nor any other of the company pilots had received any formal training in the use of this FD system, and there was no reference material available at the company to allow the pilots to study the system. The crew had flown the accident aircraft on this same scheduled route on the two previous days. These trips would have been the only exposure that the crew would have had to the operation of the FD system.

There were significant differences between the AI and FD systems. The FD system had the following features which the AI system did not: command bars; an altitude scale tied to the radio altimeter; a glide slope marker; an inclinometer; a decision height light; and a localizer scale and runway symbol. The most significant difference between the two, however, was in the method of presentation of roll attitude information. On the FD system, the bank reference was a fixed scale located on the outer part of the face of the instrument and the bank pointer rotated on the inside of this scale to indicate the roll attitude. On the AI system, the bank reference was a rotating scale located on the inside of the instrument and the bank pointer was a fixed index on the outer face of the instrument. The bank reference then for the same roll attitude was taken from different locations on the two instruments.

In addition to the above differences between the two Metro III aircraft, the accident aircraft was equipped with an autopilot, a radar altimeter, and an altitude alert system, whereas C-GSLA was not. There was no information or training provided by the company on these systems.

1.7 Meteorological Information

At 0800 PDT, there was a band of cloud associated with a weak front lying in a north-northwest/ south-southeast line across the southern Alaskan Panhandle and the northwestern tip of the Queen Charlotte Islands. There was another large cloud area to the south of Terrace which was associated with a low centred off the Oregon coast. The Terrace area was situated in almost clear air between these two areas of cloud.

The Terrace terminal forecast (FT) issued at 0330 PDT and valid at the time of the accident was sky condition partially obscured, visibility two miles in smoke and fog variable to six miles in smoke. The smoke was the result of slash burning in the local area.

Throughout the early morning of 26 September 1989, the weather observations at Terrace Airport indicated a partially obscured sky condition with scattered cloud at 500 feet agl and visibilities of two to five miles in smoke and fog. The 0800 PDT surface observation reported:

> sky condition partially obscured 600 feet scattered, 3,500 feet scattered, 12,000 feet scattered, estimated ceiling 25,000 feet broken, visibility five miles in smoke and fog, wind calm, remarks visibility south one mile due to patchy fog, and shallow fog on field.

A special observation issued at 0814 PDT was essentially unchanged from that at 0800 PDT except for the remarks which stated that the visibility to the south was now one-half mile in fog and there was a fog bank on the field.

At the time Flight 070 was carrying out the circling procedure to runway 15, the weather services observer was in the process of taking another special observation. Although he did not see the aircraft at any time, he followed the sound of the aircraft until it struck the trees. That special observation recorded at 0828 PDT reported:

> sky condition partially obscured, estimated ceiling 12,000 feet broken, 25,000 feet broken, visibility two miles in fog and smoke, wind calm, remarks visibility south one quarter mile, fog bank on field. The cloud type and opacity were fog 8/10, altocumulus 1/10, cirrus 1/10.

A further special observation, taken at 0834 PDT, reported:

> sky condition partially obscured, estimated ceiling 12,000 feet broken, 25,000 feet broken, visibility one half mile in smoke and fog, and wind calm. The cloud type and opacity were fog 8/10, altocumulus 1/10, cirrus 1/10.

At 0840 PDT, another special observation was taken indicating:

> sky condition ceiling indefinite, 100 feet obscured, visibility one eighth mile in fog, and wind calm. The opacity was fog 10/10.

Nine minutes before the accident, a Lear Jet landed on runway 15. The pilot of the Lear Jet radioed to the crew of Flight 070 that there was a "hole" over the top of the airport near the position of the localizer shack through which an aircraft could descend and then circle for runway 15. When interviewed following the accident, the Lear Jet crew indicated that, at the time of their approach and landing, there was fog on the west side of runway 15 and at the departure end of runway 15, but that the area above the threshold of runway 15 and over the terminal buildings was open.

The following is a summary of witness accounts of the weather from the time the Lear Jet landed until just after the occurrence. At the time the Lear Jet landed, the fog bank reported in the 0814 PDT observation obscured the threshold of runway 33. This fog bank was slowly moving from southwest to northeast. The leading edge of this fog bank was not vertical, and, consequently, at the time that the Lear Jet landed, the ceiling over runway 15/33 was a gradual slope upwards from ground level half-way down runway 15/33 to around 200 feet agl over the threshold of runway 15. At the time of the occurrence, the threshold of runway 15 was visible to the weather services observer; however, it could not be determined whether this threshold was visible to the crew of the accident aircraft. Immediately following the occurrence, fog completely covered all of runway 15/33. The helicopter pilot who

located the crash site estimated that the fog bank was 300 feet thick.

The 0840 PDT special observation required that an immediate amendment be made to the Terrace terminal forecast because of the decreased visibility. A revised forecast was not immediately issued as the forecaster was already in the process of preparing a new forecast for a 0900 PDT release.

1.8 Aids to Navigation

The Terrace Airport is served by the following approach aids: two NDBs, a localizer, and a DME facility. The TERRACE NDB is located 5.1 nautical miles to the southeast of the airport, and the KITIMAT NDB is 25 nautical miles to the southeast. The KITIMAT NDB was not listed in the Radio Navigation and Communications section of the Canada Flight Supplement (CFS). The localizer transmitter is located approximately 1,500 feet to the northeast of the thresholds of runways 21 and 27.

The airport has three non-precision published instrument approaches. All instrument approaches are oriented from south to north over Kitimat and Lakelse Lake. Only circling minima are authorized.

A check of the airfield approach aids by a TC aircraft was carried out at 1600 PDT on the day of the accident. At the time of this flight, all required approach aids for the LDA/DME C approach appeared to be operating normally. This flight also determined that the KITIMAT fan marker was unserviceable. The fan marker had been listed as unserviceable prior to the accident in the Notice to Airmen (NOTAM).

1.9 Communications

Both Vancouver Tower and Vancouver Centre reported normal communications with Flight 070 while the aircraft was under their control. At 0814 PDT, while under Vancouver Centre control, the crew of Flight 070 contacted Terrace FSS and requested the latest weather observation. The Terrace FSS specialist passed the Terrace 0800 observation.

At 0820 PDT, Vancouver Centre cleared Flight 070 for an approach to Terrace Airport, and, at 0821 PDT, the crew contacted Terrace FSS and reported that they had been cleared for an approach and that they were planning to land on runway 33. The Terrace FSS specialist informed

Flight 070 that the visibility to the south was now one half mile and that a Lear Jet which had just landed had been unable to land on runway 33 and had to circle and land on runway 15. The crew of Flight 070 responded that they would plan to land on runway 15. At this point, the Lear Jet crew informed Flight 070 that runway 15 or 21 would be a better choice than 33.

At 0826 PDT, Flight 070 reported by the TERRACE beacon inbound. The FSS specialist then informed Flight 070 that the winds were calm and that the approach lighting was on full for runway 15. This was acknowledged by the crew, and that was the last radio transmission from the aircraft.

1.10 Aerodrome Information

Terrace Airport is a triangular-shaped airfield situated at the intersection of the Kitimat Valley and the Skeena River. The airfield reference elevation is 713 feet asl. Runway 15/33 is 6,000 feet long by 150 feet wide. Other available runways are 03/21 and 09/27. Because of the orientation of the valley and the surrounding hills and mountains, most flight crews prefer to use runway 15/33. At the time of the accident, the approach and runway lights were on setting "5", the highest setting, and the runway end strobe lights were on.

1.11 Flight Recorders

1.11.1 Recovery and Data Retrieval

The aircraft was equipped with a Fairchild 15600-501 five-parameter foil flight data recorder (FDR) and a Fairchild A100A cockpit voice recorder (CVR). Both recorders were recovered from the wreckage. The outer cases of both were scorched during the post-impact fire, and there was some impact-related damage to both cases.

The FDR was capable of recording five parameters on a time base: heading, airspeed, altitude, vertical acceleration, and very high frequency (VHF) keying. The heading function was found to be unserviceable; consequently, heading information had not been recorded. FDR parameter plots are found at Appendices C and D. The FDR tape required cleaning to remove a sooty deposit which was a result of thermal exposure during the post-crash fire, but the tape was otherwise in good condition. The standard calibration equations for foil recorders were used, because calibration

information was not available from the operator. Damage to the FDR precluded a calibration of the recorder pitot/static system.

The CVR tape was found to be in good condition. The recording was of excellent quality. All four channels were clear, and the recorded sounds were easily discernible.

Both recorders ceased to function because of an apparent loss of electrical power a few seconds prior to ground impact. It is suspected that the damage sustained by the right wing during the initial impact resulted in the loss of power.

The information obtained from the flight recorders has been incorporated into appropriate sections of this report.

1.11.2 FDR Waiver

ANO Series II No.13 requires that large passenger-carrying aircraft be equipped with a 16-parameter FDR. However, TC AARCB 1989 Policy Letter No.10 permits waivers for commuter-category aircraft such as the Metro III to operate with a six-parameter digital FDR. There was no documentation in either Skylink or TC files to indicate that a waiver had been requested or granted to permit the accident aircraft to operate with a five-parameter foil FDR.

1.11.3 FDR Serviceability

ANO Series II No.13 requires that the installation, accuracy, and calibration results be in accordance with the Engineering and Inspection Manual. This Manual also requires that a maintenance plan including procedures for periodic readout of the recorded data be provided to TC and that operators be able to produce on demand current calibration and correlation data with respect to each aircraft in service. In the case of the accident aircraft, there was no company or TC documentation on the maintenance plan or the calibration data.

1.12 Wreckage and Impact Information

The aircraft initially struck a number of 65-foot-high trees in a wooded area 1,560 feet to the west of runway 15. The aircraft clipped the trees on a heading of 162 degrees magnetic (M) in approximately level flight, in a slightly right-wing-low attitude. These tree strikes tore the outboard eight feet off the right wing as well

as an additional eight feet from the underside of the wing. The aircraft then crossed Beam Station Road, and the left wing cut two hydro cables on the west side of the road before the aircraft struck the ground in a 45-degree right bank. The stub of the right wing struck the ground first, and the aircraft rolled to an almost inverted position before the fuselage struck the ground. The aircraft suffered severe damage during the crash sequence because of the high impact speed and the presence of large trees at the ground impact location. An intense fire erupted immediately following the initial ground impact. The wreckage in this area was distributed about a mean heading of 179 degrees M.

Extensive breakup of the left wing and the remaining portion of the right wing occurred immediately following the initial contact with the ground and the hydro lines. The right propeller separated from the engine and was found 100 feet from the first ground impact mark. Large portions of both wings and the horizontal stabilizer were stripped from the aircraft as it penetrated the trees. Both engines together with the aircraft centre section came to rest approximately 180 feet from the initial ground impact point. The left propeller also separated from its engine and was found 30 feet beyond the engines.

When the aircraft struck the ground, the right propeller cut four visible swathes in the sandy soil. Calculations based on a propeller speed of 1,591 rpm indicate a ground speed of 147 knots at ground impact.

The total length of the wreckage trail from the location of the first piece of wreckage found at the site of the initial tree strike to the last piece of wreckage found on the west side of the road was 1,024 feet. The initial ground contact occurred 750 feet from the first tree impact.

Selected items of wreckage were shipped to the TSB Engineering Laboratory for further examination. These items included both engines, both propellers, the landing gear and flap actuators, some cockpit instruments and warning/caution lights, the stall avoidance system (SAS) components, and various other systems components.

1.12.1 Engines and Propellers

Disassembly and detailed examination of the left engine revealed the following: the tips of the vanes of the second stage of the centrifugal compressor and areas of the surrounding shroud were ground away; there were rotational score marks on the second direct drive fuel

control gear; the high speed pinion coupler driveshaft was sheared just forward of the drive gear; and metal spray deposits from the compressor vanes and shroud were present on the turbine diffuser vanes and wheel blades. These conditions indicate that, at the time of ground impact, the left engine was turning at high speed, generating high temperature in its combustor, and had a high speed gas flow impinging on its turbine. It was, therefore, producing power, probably high power.

There were similar indications on the right engine. There was considerable grinding between the compressor vane tips and their shroud, and the high speed pinion coupler driveshaft was sheared forward of the drive gear. In addition, several of the ring gear assembly mount studs in the forward face of the diaphragm were displaced laterally, indicating a sudden engine stoppage due to a propeller strike. The metal deposits from the compressor vanes and shroud found in the turbine area indicated that the right engine was operating at a lower temperature at ground impact than the left engine. In addition, the presence of carbon marks from the burnout of pine needles in the turbine section indicated a lower than normal operating temperature. This can be explained by the following: the right engine ingested tree branches during the initial contact with the trees on the east side of Beam Station Road whereas the left engine did not; and the fuel supply to the right engine was likely disrupted at the time that the outboard portion of the right wing was torn away. As a result, the right engine began to lose combustion several seconds prior to ground impact.

Both propellers were severely damaged in the accident, and the pattern of damage to both propellers was similar. This damage was consistent with both propellers rotating at the moment of impact, with both having a similar magnitude of rotational energy and with both producing positive thrust.

The approximate blade angle at impact for both propellers was in the region of 35 degrees. These angles were derived from examination of the impact marks on the bottom face of the blade root made by impact with the crosshead flange. Because the propeller blades were forced to coarser angles by crash loads, the primary blade impact angle is the finer angle determined from the impact marks. The 35-degree blade angles indicate that at impact both propellers were at a setting corresponding to high thrust.

The propeller governor for the left engine and the fuel control units for both engines were bench-tested at the

manufacturer's facility. The components from the left engine were found to be functioning normally. The right engine fuel control unit was badly damaged; however, the limited testing which could be carried out on this unit indicated that the unit was functioning. Damage to the right propeller governor precluded testing of this item. Disassembly of the two components which could not be fully tested did not reveal any pre-impact failures.

1.12.2 Structures

Detailed examination of the wreckage was able to account for both wings, both ailerons and aileron trim tabs, both flaps, the horizontal stabilizer, both elevators, the vertical fin, and the rudder and rudder trim tab. It was established that all flying surfaces and flight control surfaces were intact at the time of the initial impact with the trees.

A particular damage pattern caused by the initial tree strikes permitted an assessment to be made of the attitude of the aircraft at the time of initial impact. This assessment determined that the aircraft was approximately wings level and that the fuselage was approximately horizontal at the time of the initial tree strikes.

1.12.3 Systems

1.12.3.1 Hydraulic

The hydraulic power pack, which stores fluid for system use, was crushed during the impact and therefore depleted of fluid. The two hydraulic shut-off valves were recovered and found to be in the open position. The engine driven hydraulic pumps remained attached to the engines, and functional testing indicated that both appeared to be serviceable.

1.12.3.2 Flight Controls

The almost total destruction of those portions of the flight controls in the cockpit area and in the wing centre section area precluded any assessment of the overall serviceability and integrity of the flight control systems prior to impact. Examination of those control push-pull tubes which were not destroyed did not reveal any pre-impact failures. All control cable breaks were consistent with impact-related overload fractures. In areas where turnbuckles and bellcranks were not destroyed, the control cables were found still attached. There was no evidence to indicate any control system malfunctions or failures prior to impact.

1.12.3.3 Flaps

The flap control lever in the cockpit and the flap position transmitter in the centre wing area were destroyed in the post-crash fire. A witness mark on the wall of the left flap actuator cylinder caused by the piston indicated that this flap was in the full-up position. The right flap actuator was found at the site lodged in a pile of molten metal. It was badly damaged; the cylinder was split open, and the piston was trapped at the mid-travel position. Although this damage prevented any assessment of the position of this flap at impact, it is considered likely that this piston was moved to the mid-travel position by the impact and breakup forces. Both flaps had relatively minor damage to the leading and trailing edge areas which would tend to indicate that they were protected by the wing structure during the crash sequence and therefore in the up position. It was concluded that the flaps were up at impact.

1.12.3.4 Landing Gear

The portion of the centre pedestal containing the landing gear selector was recovered with the selector lever in the up position. The hydraulic actuators for the left main and nose gears were recovered. Witness marks on the cylinder walls of these actuators indicated that the left main and nose gears were up or nearly up at the time of impact. In addition, the relatively light damage to the left main and nose gears indicates that they were protected by the aircraft structure at impact and therefore in the up position. The right main gear was destroyed in the fire, and no assessment of the position of this gear could be made. It was concluded that the landing gear was up at impact.

1.12.3.5 Fuel

The fuel boost pumps, fuel shut-off valves, and the fuel cross-flow valve were recovered from the wreckage. The boost pumps were badly damaged and could not be functionally tested. The shut-off valves were determined to be open and the cross-flow valve closed. The positions of these valves are consistent with the normal operation of the fuel system.

1.12.3.6 Cockpit Warning Lights and Instrumentation

The annunciator panel contained 48 lamp segments, five of which had been destroyed in the crash. Of the remaining segments, six were identified as spares. Microscopic examination of the remaining segments determined that they were off at impact.

Except for one airspeed indicator and the dial face of an altimeter, the remaining instruments were destroyed in the crash or damaged to the extent that an analysis was not possible. Examination of the airspeed indicator for pointer imprints and sector gear mating damage did not reveal any useful information. The altimeter dial face still contained the adjustable barometric pressure scale which was indicating 30.00 inches of mercury. Detailed examination of the rotating portions of the scale and the setting knob did not show any evidence of scale rotation by impact forces.

1.12.3.7 Stall Avoidance

All Metro II and III aircraft are equipped with a SAS to warn the pilot of an impending stall and, if necessary, to provide an artificial nose-down pitching moment to prevent a stall. The SAS senses an impending stall by means of a fuselage-mounted angle of attack (AOA) transmitter. This transmitter sends an electrical signal to a computer which, depending on flap position, determines whether the aircraft is approaching a stall. The SAS computer calculates the ratio of airspeed (V) to stall speed (V_s). At 1.12 V_s, a warning horn will sound and, at 1.02 V_s, a stick pusher will actuate. In the Metro III, an airspeed switch disables the stick pusher above 140 knots. The stick pusher consists of a servo, a capstan assembly, and an independent cable system which connects the capstan to the elevator control.

Because of the severity of the crash and subsequent fire, not all of the SAS components were recovered. The missing components were the airspeed switch, the control box, the clutch switch, the test switch, and the associated circuit-breakers. The computer was recovered but was damaged in the fire and did not provide any useful information. The stick pusher servo, the SAS indicator, the AOA indicator, and the SAS fault lights were recovered and examined. The examination of the servo indicated that the DC motor was energized and rotating at idle speed prior to impact and that the outer casings of both clutches were being rotated normally by the DC motor at impact. Both of these conditions occur during normal system operation, that is, when the system is not activated. The SAS and AOA indicators did not reveal any information about their readings at impact, and the SAS fault lights were determined to be off at impact.

One anomaly was discovered during the examination of the stick pusher servo. A Federal Aviation Administration (FAA) AD 85-22-06, called for the

removal of the left clutch as per the Fairchild Service Bulletin (SB) SBA27-004; however, this clutch had not been removed. The SB also called for two wiring changes. The examination confirmed that one of these wiring changes had been made, but, because of fire damage, it was not possible to confirm the other change. Records obtained from the maintenance facility in the FRG that carried out this work indicated that this AD had been completed. It appears that the wiring changes called for had been made and that the left clutch was electrically inoperative. Although this clutch was still installed, there was no evidence that it had adversely affected the operation of the servo.

1.12.3.8 Other

The severe impact and fire damage to the electrical, fire protection, pneumatic, and oxygen systems prevented definitive findings with regard to these systems. Components of these systems which were recovered showed no evidence of pre-impact failure or malfunction.

1.13 Medical Information

The autopsy results indicate that both crew members were fatally injured on impact. The autopsies did not reveal evidence of any pre-existing conditions which could have affected the crew's performance.

Toxicology testing was carried out by the Civil Aviation Medical Unit (CAMU). The captain tested negative for carbon monoxide (CO), hydrogen cyanide (HCN), ethanol, and a drug screen. The co-pilot's blood sample yielded a value of 17 milligrams per cent (mg%) of ethanol, a small amount of acetaldehyde and no other volatiles. Some tissue evidence of ethanol was noted; however, the values, when detectable, were below the reporting threshold of anything greater than 10 mg% for CAMU. No other volatiles were detected in the tissues. Urine and vitreous humor samples were not available for ethanol testing to assist in the verification of the blood findings.

The co-pilot's roommate was questioned about the co-pilot's activities in the 24 hours before the accident. He indicated that, on 25 September, at about 2000 PDT, he met the co-pilot at the airport when he returned from a flight. The roommate stated that the co-pilot did not consume any alcohol from the time he met him until the co-pilot went to bed. Further investigation revealed no history of ethanol intake

following the ingestion of one beer at a party Saturday night, some 58 hours prior to the accident.

It is concluded that the presence of a low level of blood ethanol, in the absence of a positive history of ingestion prior to the accident is explained on the basis of post-mortem production of ethanol. This would be consistent with the trauma sustained by the victim in the accident, which would have resulted in bacterial seeding and with the period of time during which the blood was unpreserved from death till autopsy. Thus, the blood ethanol finding is determined to be invalid and not of significance.

1.14 Fire

The initial tree strike on the east side of Beam Station Road ruptured the fuel tanks in the right wing. This fuel was ignited on initial ground impact on the west side of the road, and an intense fire followed. The cockpit and main cabin area were extensively damaged in the fire.

1.15 Survival Aspects

During the impact with the trees and ground, the aircraft structure broke up to the extent that only the tail section of the fuselage was left relatively intact. The aircraft was further destroyed in the post-crash fire. The bodies of the crew were found in an area where most of the cockpit instrument panel was found. The bodies of the passengers were found within or near the area which contained the primary wreckage of the passenger cabin structure. The destruction of the cockpit and cabin areas precluded any evaluation of the effectiveness of seats and seat-belts. The accident was not survivable.

1.16 Tests and Research

1.16.1 Simulator Trials

1.16.1.1 Purpose

Simulator trials were conducted on an FAA approved simulator. The primary purpose of these trials was to establish, as near as could be determined, the pitch and roll attitudes of the aircraft throughout the missed approach procedure. Basic aircraft performance and systems data were also determined as well as the performance capabilities of the simulator/aircraft

during a missed approach procedure with the introduction of various mechanical failures/malfunctions.

1.16.1.2 Method

The evaluations were conducted using the weight pertinent to the accident flight and a C of G calculated with the assumption that the five passengers were evenly distributed from front to rear in the cabin. In those profiles flown to establish the aircraft attitude, the missed approaches were commenced, as near as was possible and/or practical, at the airspeed and altitude agl indicated on the FDR and with the aircraft trimmed for level flight and configured as per the accident aircraft; subsequent power, configuration, and pitch trim changes were then made as per those indicated on the CVR. No elevator control inputs were made. Missed approaches were flown with roll attitudes of 0, 30, and 45 degrees of right bank established during the missed approach climb and maintained until impact. The various mechanical failures/malfunctions introduced were associated with one of an uncommanded SAS activation, a runaway trim, or an engine failure, with each occurring at the point of initiation of the missed approach.

1.16.1.3 Results

The data from these simulator trials were compiled to arrive at a "pitch attitude profile" for the accident aircraft which could then be used for analysis purposes. The result of this compilation is contained at Appendix E.

The consistency of the results from the individual simulator runs indicates a reasonable degree of confidence in the accuracy of the profile at Appendix E in duplicating the accident aircraft pitch attitude during the missed approach sequence. For example, the times from the initiation of the missed approach to impact for the two wings-level simulator profiles were 21 and 23 seconds, which are consistent with the 22 second time for the accident sequence. The missed approach profiles flown with roll attitudes of 30 and 45 degrees of bank resulted in ground impacts in 20 and 16 seconds respectively. The impact airspeeds recorded for all profiles were also consistent with the initial impact airspeed taken from the FDR once any differences in initial terrain clearance between the accident aircraft and the individual simulator runs were taken into account.

The following was also determined from the simulator trials:

1. Engine acceleration from 55 per cent torque (level flight, flaps full, and gear down) to full power takes two to three seconds;

2. Landing gear retraction requires six seconds;

3. Flap retraction from full down to the half flap position takes eight seconds and to the up position 14 seconds;

4. The application of full power during a missed approach manoeuvre produces a nose-up tendency; the simultaneous up selection of gear and flaps will slightly increase this tendency;

5. Seventeen nose-down trim beeps from the trimmed condition at the commencement of the missed approach result in full nose-down trim; and

6. The performance of the simulator was such that a missed approach in accordance with check-list procedures could be readily carried out with either an uncommanded SAS activation, a runaway trim, or an engine failure occurring at the point of power application.

1.17 Additional Information

1.17.1 Emergency Locator Transmitter

An emergency locator transmitter (ELT) signal was not received by the FSS at the time of the accident. Inspection of the ELT prior to removal from the wreckage indicated that the switch on the ELT was in the AUTO position and that the fuselage-mounted antenna had been broken and disconnected from the transmitter during the crash sequence. Prior to removal of the ELT from the wreckage, a portable receiver was used to confirm that the ELT was not emitting any signal. After the ELT was removed from the wreckage, the switch was cycled to the OFF and then the ON position, and a strong ELT signal was received both at the FSS and at the portable receiver.

Further examination of the ELT revealed that the "G" switch had activated but that the signal was intermittent. The intermittent operation was traced to an intermittent resistor-capacitor junction. It is likely that this junction was open on impact, and, consequently, the ELT did not function.

1.17.2 Crash, Firefighting, and Rescue (CFR) Services

The document "Transport Canada Crash, Firefighting, and Rescue Services Standards, AK-12-03-001" describes the method by which airports are categorized to determine the CFR requirements. It takes into consideration the size of the aircraft and the frequency of aircraft movements. This document states in 3.08 (b) (ii) "At airports other than (i) above, (i.e., designated regular international airports), used by scheduled passenger air carrier service, and providing that resources are available for the provision of CFR protection, service will be established to coincide with such aircraft movements at least one-half hour before and after the aircraft movement."

The CFR availability times for the Terrace Airport published in the CFS were 0830 to 1930 PDT. These times had been amended by a NOTAM to 0930 to 2030 PDT. The firefighters' duty times were one-half hour before to one-half hour after the NOTAM times to allow for start-up and shutdown activities, which effectively extended the CFR coverage from 0900 to 2100 PDT. The airport manager, on his own initiative, further extended this period of CFR availability by having the airport fire chief start his shift at 0800 PDT. This provided coverage at a reduced level between 0800 and 0900 for early morning aircraft movements. Therefore, the effective availability of CFR services at Terrace was from 0800 to 2100 PDT. Without these unofficial extensions of CFR coverage, CFR services would not have been available at the time of the occurrence.

A survey of all scheduled flights operating to and from Terrace indicates that some operators do operate scheduled flights outside even the extended hours of CFR availability. In these cases, the airline does have the option to request that CFR be available; however, if the airline does make this request, it must bear the cost of the call-out of the CFR crew. For the majority of these flights operating outside the CFR hours, it is the policy of some companies not to request the call-out of the CFR crew.

1.17.3 Airport Disaster Plan

TC airport disaster planning standards are published in the document "Policy, Standards, and Guidelines for the Development of an Airport Disaster/Emergency Plan and the Conduct of Exercises at Transport Canada Airports, AK-13-01-002." This document outlines the disaster plan requirements and states that the plan shall be developed and maintained by the airport manager, in coordination with other agencies as

appropriate. The Terrace Airport Emergency Plan was found to be consistent with the relevant TC policy and guidelines.

For accidents which occur within five miles of Terrace Airport, the Terrace Airport Emergency Plan assigns the responsibility for CFR to the airport fire department. The Plan calls for the vehicles from the Thornhill Fire Department, the Terrace (city) Fire Department, the RCMP, and the BC Ambulance Service to proceed to the airport fire hall. The movement of these vehicles would then be controlled by a team, composed of the senior member from each agency, which would remain at the Emergency Command Centre set up at the airport fire hall. The airport fire chief was to have overall control of the CFR activities.

When the alarm sounded at 0829 PDT, the crash site and parts of the airport were covered in thick fog. Because of the fog, the location of the site was not immediately apparent, and a local helicopter was used in an attempt to locate the site from the air. The helicopter pilot was able to locate the smoke from the crash site rising above the fog; however, he could only approximate the position of the site on the ground.

At the airport fire hall, the fire chief was on duty from 0800 PDT. When the alarm sounded, he set out alone in one of the two airport fire trucks to search for the aircraft in the heavy fog. He searched runway 15/33 and then went to Beam Station Road and found the crash site at 0853 PDT with guidance from the helicopter pilot. The fire chief commenced fighting the fire as soon as he arrived on site, and he quickly had the fire under control. By 0930 PDT, the fire was extinguished, and the fatalities had been confirmed.

The Terrace Fire Department, the Thornhill Fire Department, and the RCMP all responded to the accident. All proceeded to the airport fire hall as called for in the Emergency Plan, and they were then escorted to the crash site. The Terrace Fire Department was the first to arrive at the fire hall, and, at that time, the fire hall was unmanned as the fire chief had already departed for the site and the 0900 shift had not yet arrived. Shortly thereafter, the 0900 shift arrived, and they were able to escort the other agencies across the airfield to the site.

Except for the lower mainland and Vancouver Island, all BC ambulances are dispatched by the BC Ambulance Dispatch Centre at Kamloops. The dispatch centre receives telephone requests for ambulance services and dispatches the nearest available ambulance. For this

accident, Kamloops dispatch should have been notified by the Terrace RCMP; however, this was not done. Kamloops dispatch was informally notified of the accident at 0842 PDT by the Terrace stand-by ambulance attendant. The Kamloops centre responded to this by alerting a second ambulance crew for duty. At 0844 PDT, Kamloops dispatch was formally notified of the accident by the BC Ambulance Services provincial headquarters which had been alerted by the Rescue Coordination Centre. From that point on, the BC Ambulance service response followed the approved emergency response procedures.

The first ambulance was dispatched to the airport and the second one to the Beam Station Road in case the aircraft had crashed to the west of the airport. While proceeding up the Beam Station Road, the driver of the second ambulance heard the Terrace Fire Department trucks on the radio scanner and learned that the crash site had been located on the Beam Station Road; however, shortly after this, when he was told by Kamloops dispatch to proceed to the airport, he did not indicate that he knew the location of the accident and followed the dispatcher's instructions. The result of this lack of communication was that both ambulances ended up at the airport. At this time, the Kamloops dispatcher thought that the ambulance crews would have to be flown to the site by helicopter. When it was realized that this was not necessary, both ambulances drove from the airport to the crash site. The end result of these delays was that ambulance services were not available at the crash site until 45 minutes after the accident or 32 minutes after Kamloops dispatch had been notified of the accident. Since this accident, the BC Ambulance Service has instructed their ambulance crews to report to the dispatch centre any dispatch-related information of which they become aware during an ambulance call.

1.17.4 Transport Canada/Skylink Interface

1.17.4.1 Operating Certificate

Skylink Airlines, based at Vancouver, was granted Operating Certificate (OC) Number 6152 on 07 February 1989 for domestic, non-scheduled international, and scheduled international service between points in Canada and between points in Canada and abroad. Terrace was an approved point listed in Amendment Number 1 to the Operating Specifications.

1.17.4.2 Operating Specification Waiver

The Metro III aircraft has a maximum take-off weight (MTOW) of 14,500 pounds which qualifies it, by definition, as a large aeroplane. Operating standards and practices pertaining to the operation of large airplanes are contained in ANO Series VII No.2. Skylink Airlines had been granted a waiver by TC (Amendment Number 4 to the Operating Specifications) to operate the Metro III aircraft under ANO Series VII No.3, Standards and Procedures for Air Carriers using Small Airplanes in Air Transport Operations. There are significant differences between these two standards, in particular in the requirements for crew training, qualifications, and check-rides.

Some of the specific items which are required under ANO Series VII No.2 but are not required under ANO Series VII No.3 are as follows:

1. Appropriate recurrent training at least once every 12 months.

2. Written exams at the completion of the ground training phase.

3. Flight training on rejected landings from 50 feet with simulated instrument flight rules (IFR) conditions from 100 feet.

4. Demonstrated pilot knowledge of the route being flown plus route checks and route currency.

5. PPCs every six months including certain assessments under IFR or simulated IFR conditions.

6. Demonstrated pilot ability to fly circling approaches.

7. Demonstrated pilot ability to fly missed approaches including a failure of a critical engine under simulated IFR or in a simulator.

The operator had not incorporated any of the above ANO Series VII NO.2 requirements into their own monitoring and training programs nor were they required to do so.

Interviews with regional TC inspectors revealed that they do not simulate IFR conditions during check-rides because of safety concerns and the lack of an acceptable method of simulation.

Subsequent to this accident, TC changed its policy and issued TC AARCB Policy Letter No.10, dated 12 January

1990, which stated that, effective immediately, any companies wishing to introduce commuter-category aircraft into commercial service would be required to operate these aircraft under ANO Series VII No.2 and that those carriers that had been granted waivers to operate commuter-category aircraft under ANO Series VII No.3 vice No.2 were required to transition to No.2 requirements by 01 April 1990.

1.17.4.3 Pilot Proficiency Checks (PPC)

Skylink Airlines had requested permission from TC to group the Metro II and Metro III aircraft for the purposes of PPCs. This would allow a pilot who held a PPC on the Metro II to qualify for a PPC on the Metro III without doing a Metro III PPC ride with a TC inspector. The pilot would have to complete an aircraft differences course and a flight with the company training pilot. Although TC had not formally replied to Skylink's request, the request had been recommended for approval within TC, and, in fact, verbal approval had been given by an air carrier supervisor to his inspectors. In addition, one of Skylink's Metro II pilots had been granted a Metro III PPC without having to complete a Metro III PPC ride with a TC inspector.

The Metro III aircraft MTOW exceeds that of the Metro II by 2,000 pounds and the Metro III wingspan is 10 feet longer. The engines of the Metro III produce more thrust, and the propellers are four-bladed vice three for the Metro II. Despite these differences, TC considered the handling characteristics of the two aircraft types to be similar to the extent that they could be grouped for PPC purposes.

1.17.4.4 Transport Canada Surveillance/Enforcement

TC had conducted nine formal audits on the company since 1985. Two of these audits had resulted in suspensions of the OC on 10 September 1987 and on 24 June 1988. In addition, warnings of potential suspensions were considered on three other occasions. The reasons for the first suspension on 10 September 1987 were as follows:

1. Failure to employ an Operations Manager and Chief Engineer as required by ANOs;

2. Permitting flight crews not qualified in accordance with ANOs to act as pilot-in-command;

3. Failure to exercise satisfactory operational control; and

4. Operating an aircraft not maintained and released in accordance with the company approved maintenance manual contrary to ANOs.

The reasons for the second suspension on 24 June 1988 were essentially the same with the addition of the following: operating aircraft that were unsafe and unfit in all respects for flight. In the case of the first suspension, the OC was reinstated four days later, on 14 September 1987, and, in the second case, the next day on 25 June 1988. In both cases, the company submitted an account of the corrective actions they had taken to satisfy the conditions of reinstatement, and TC accepted this account as proof of conformance.

Because of this accident, TC decided to advance an audit which was scheduled for November 1989. On 30 September 1989, as a result of the initial findings of the audit team, TC suspended the OC of Skylink Airlines under Section 7.1(1)(b) of the Aeronautics Act for "loss of operational control." On 06 October 1989, as a result of the same audit, TC cancelled the OC pursuant to the same section of the Aeronautics Act for "incompetency on the part of the document holder and failure to comply with the conditions subject to which the document (OC) was issued." Specifically, similar non-conformance findings to those which resulted in the previous OC suspensions, as well as others, were uncovered during this audit.

During the four years that the company was operating, the ongoing operational surveillance conducted by TC resulted in numerous infractions against the company for regulatory violations. Many of these were repeat infractions. The most significant of these was a ramp inspection at Terrace on 20 April 1988 which resulted in a large number of charges being laid and, eventually, the levy of a $25,000 fine. An additional area of concern for TC was the high turnover rate of personnel in key positions such as Operations Manager, Chief Pilot, and Director of Maintenance.

1.17.5 Company Operations

Skylink Flight 070 was a scheduled domestic flight. Pre-flight procedures were carried out in accordance with the TC approved Skylink Operations Manual (OM). The company utilized a pilot self-dispatch system, and the pilots were responsible for preparing all the necessary documentation prior to flight. The Skylink

Flight Report Form FR-1 and the Weight and Balance form were completed and signed by the captain just prior to flight. Form FR-1 recorded individual passenger weights, baggage/cargo weights, fuel weight, and gross take-off weight. A copy of this form was retained at the dispatch location. The Weight and Balance form contained specific information on the seating arrangement of the passengers and the distribution of the baggage and cargo. This form was carried on board the aircraft; a copy was not retained at the dispatch location. In the case of the accident aircraft, this form was destroyed in the crash which prevented the calculation of an accurate C of G.

The company did not employ Standard Operating Procedures (SOPs), nor were they required to do so. There is little if any direction available in the way of standards or guidance which could be used by companies to develop SOPs or similar documents. It was determined that the company was in the process of drafting a set of SOPs; however, company personnel were unable to indicate the exact status of these SOPs. Interviews with company pilots indicated that there was often confusion among the pilots about what operational policies or directives were in place. Pilots indicated that they would often get different direction from different supervisory personnel.

1.17.6 Company Training

The Skylink training syllabus was contained in the TC approved Company OM. Although it was evident from the records that both pilots had received the mandatory initial and recurrent training required, the training records of the pilots were incomplete in some areas and the record-keeping was inconsistent. Both pilots had received the Metro II/III differences course prior to transition to the Metro III. Neither pilot had received any formal flight safety, cockpit resource management (CRM), or simulator training while with the company, nor was any such training required by regulation.

1.17.7 Maintenance Control Manual (MCM)

The company MCM was approved by TC on 03 August 1989. Section 2.1.2 of the MCM indicates that there are six licensed engineers employed at the company. A review of the TC files, however, indicates that one of these individuals was an apprentice and required six months training/experience before a licence could be issued. Flight crews and line mechanics were authorized to perform specific elementary maintenance tasks for which maintenance release was not required. All personnel

granted this authority were to be issued a company maintenance approval card indicating the tasks for which they were trained. These approval cards had not been issued.

1.17.8 Circling Approach Minima

The published circling minima or MDA for the LDA/DME C approach are 1,240 feet asl for Categories A, B, and C aircraft (circling manoeuvre airspeed up to and including 140 knots) and 1,600 feet asl for Category D aircraft (circling manoeuvre airspeed from 141 to 165 knots inclusive). In general, a higher MDA is required for a higher speed to compensate for the increased aircraft turning radius at this higher speed.

The AFM does not specify a minimum circling speed for the Metro III; however, interviews with other company Metro III pilots indicated that they considered 140 knots to be the minimum acceptable speed until landing was assured. In the case of the accident aircraft, although the crew briefed for the Category C MDA of 1,240 feet asl, the aircraft speed was above 140 knots except for a short four-second period prior to the missed approach. Several other company pilots also selected the 1,240-foot MDA when questioned as to what they would choose under similar circumstances.

1.17.9 Circling Approach Visual Requirements

The definition of "required visual references" from the Air Regulations Section 101, which is repeated almost verbatim in the Aeronautical Information Publication (AIP) at RAC 9.20.3, is as follows: "In respect to an aircraft on an approach to a runway, that section of the approach area of the runway or those visual aids that, when viewed by the pilot of the aircraft, enables the pilot to make an assessment of the aircraft position and the rate of change of position, relative to the nominal flight path". There are no definitions or descriptions of the terms "the approach area of the runway", "visual aids", or "nominal flight path".

A different definition of "required visual references" is contained in the Canada Air Pilot (CAP) at GEN 14 as follows: "That section of the visual aids or of the approach area which should have been in view for sufficient time for the pilot to have made an assessment of the aircraft position and rate of change in relation to the required flight path".

In addition to these definitions, RAC 9.25 of the AIP and section 3.9.5 of the TC Instrument Procedures Manual TP2076 state, with respect to circling

approaches, that "The basic requirements are to keep the runway in sight after initial visual contact, and remain at the circling MDA until a normal landing is assured".

1.17.10 Aircraft Flight Manual (AFM) Missed Approach Procedure

The AFM does not specifically detail a missed approach procedure. The procedure to be carried out when a landing cannot be completed, i.e., an aborted landing attempt, is referred to as a balked landing procedure. This procedure is as follows:

1. Power levers - set 650 degrees Celsius or 100 per cent torque;

2. Climb speed - attain;

3. Rate of climb - establish a positive rate;

4. Landing gear - up;

5. Flaps - retract to half;

6. Airspeed - accelerate to 120 knots;

7. Flaps - up.

In this procedure, the captain is responsible for setting the power and therefore for ensuring that the engine limitations are not exceeded.

Based on the FAA approved AFM performance chart for the Balked Landing Rate of Climb (gear down, flaps down, and bleed air on), the expected rate of climb at plus seven degrees Celsius and a pressure altitude of 800 feet is 1,750 feet per minute (fpm). This rate of climb is reduced by 350 fpm to 1,400 fpm with engine anti-ice on.

1.17.11 Published Missed Approach Procedure

The published missed approach procedure for the LDA/DME C approach at Terrace calls for a climb at 0.8 DME to the localizer fan marker followed by an immediate climbing left turn to intercept a track of 134 degrees M to the TERRACE NDB. In the case of the accident flight, since the aircraft was already past the fan marker when the missed approach was initiated, the correct actions would have been to immediately establish a climbing turn to intercept a track of 134 degrees to the TERRACE NDB.

1.17.12 Spatial Disorientation

1.17.12.1 General

Errors in the perception of attitude can occur when aircrew are exposed to force environments that differ significantly from those experienced during normal activity on the surface of the earth where the force of gravity is a stable reference and is regarded as the vertical. The acceleration of gravity is the same physical phenomenon as an imposed acceleration, and hence, in certain circumstances, one may not be easily distinguishable from the other. When the imposed acceleration is of short duration such as the bounce of a car or the motion of a swing, one can separate perceptually the imposed motion from that of gravity. When the imposed acceleration is sustained, however, such as the prolonged acceleration of an aircraft along its flight path, the human perceptual mechanism is unable to distinguish the imposed acceleration from that of gravity. The body senses the sum of these two accelerations, and this resultant sum becomes the reference acceleration which is regarded as the vertical. Illusions of attitude occur almost exclusively when there are no outside visual references to provide a true horizon.

In the absence of visual cues, the percept of motion and position is sensed primarily by the vestibular organs, and hence the term vestibular illusion is used to describe the circumstances where these organs do not correctly sense motion and/or position. Experiments have shown that there are large individual differences in the magnitude of such illusions and in the time required for the illusions to develop.

1.17.12.2 Somatogravic Illusion

If one considers an aircraft flying straight and level and accelerating along the direction of flight because of an increase in power, for example, then the direction of the inertial force due to the acceleration is to the rear of the aircraft and for the purposes of this discussion can be assumed to be along the longitudinal axis of the aircraft. This inertial force combines with the force of gravity to produce a resultant which is inclined to the rear of the aircraft. If this resultant is then used by the pilot as the vertical reference, then the pilot will incorrectly sense that the aircraft is in a nose-up attitude. If the pilot then trims or eases forward on the control column to correct for this nose-up perception, the nose of the aircraft will drop and the airspeed will increase This change in attitude will

change the direction of the resultant force vector in such a manner as to maintain and perhaps magnify the illusory perception of a nose-up attitude.

Significant errors in perception can develop within the first few seconds of a change in the force environment. Experiments carried out in flight have shown that there is little lag in the onset of the illusion and that there is a relatively rapid increase in its magnitude during the initial six to eight seconds. This illusion is known as the somatogravic illusion, and it is particularly dangerous when it occurs on take-off or when overshooting, especially at night or in poor visibility. An aircraft deceleration will result in the opposite effect, that is, a perceived nose-down attitude.

The apparent or perceived gravity vector which would have been experienced by the crew during the missed approach was derived using the aircraft vertical acceleration and the derivative of the aircraft velocity from the FDR and the aircraft pitch determined from the simulator trials. This derivation is contained at Appendix E. There were some limitations imposed on these calculations and the analysis of them because of the absence of heading information and the fact that the FDR did not record aircraft attitude or control inputs.

1.17.12.3 Somatogyral Illusion

The simplest example of a somatogyral illusion is the inability of a pilot to sense accurately, other than by visual cues, the angle of bank during a prolonged coordinated turn. The pilot does have some information about the bank angle as the aircraft enters the turn from the semicircular canals which are stimulated by the angular rolling motion. Once a steady rate of turn and constant bank angle are established, however, the resultant of the force of gravity and the inertial force due to the curved flight path is parallel to the pilot's vertical axis and he perceives the aircraft to be wings level. If the recovery from the turn is made abruptly, the roll-out will be perceived as a roll-in and the illusion of a turn in the opposite direction will exist. This phenomena, commonly referred to as the leans, has been experienced by most aircrew at some time.

2.0 ANALYSIS

2.1 Introduction

The aircraft struck terrain to the west of the airport while the crew was executing a missed approach in IFR conditions following a circling procedure to land on runway 15 at Terrace. The wreckage examination at the site, the detailed examination and testing of certain components, the accounts of eye witnesses, the air traffic control (ATC) tapes, and the data retrieved from the flight recorders all indicate that the aircraft was functioning normally up to the point of initial impact. The analysis, therefore, focuses on the decisions and actions of the crew both before and during the approach and missed approach, with particular emphasis on the human performance issues.

2.2 Weight and Balance

From the weight and balance discussion at 1.6.2, it is apparent that the aircraft aft C of G limit can easily be exceeded by the improper seating of only a few passengers and that this situation can occur at weights well below the maximum authorized. If the aircraft was loaded with the passengers seated in the aft portion of the cabin such that the C of G was at or slightly beyond the aft limit, then this would have affected the aircraft handling characteristics throughout the trip and during the missed approach sequence. This condition would have increased the natural tendency of the nose to pitch up when full power was applied and the gear and flaps were retracted and would have required greater than normal control wheel forces and/or trim inputs to counteract. Any effect on the aircraft handling characteristics would have been slight, however, and control of the aircraft would not have been significantly affected.

2.3 Meteorological Conditions

At the time of the accident, the local ceilings and visibilities in the immediate vicinity of Terrace Airport were extremely variable. When the Lear Jet landed, the most significant local weather feature was a fog bank, 300 feet thick, which obscured the southern half of runway 15 and was moving in a northeasterly direction. The leading edge of this fog bank sloped upwards from the surface at a point half-way down the runway to a height of 200 feet over the threshold of runway 15.

At 0827:29 PDT, the time of the captain's call "OK, I got the button here", the aircraft was at an altitude of 1,200 feet asl (approximately 500 feet above the airport reference elevation) and just slightly more than one nautical mile from the localizer transmitter, approaching the MAP. This position, assuming the aircraft was established on the published inbound track for the approach, was approximately 10,000 feet from the button of runway 15. Using the distances and heights of the aircraft and the fog bank relative to the button of runway 15, it is evident that the button of runway 15 would not have been visible to the crew over the fog bank at this point in time. This conclusion is further supported if both the sloping leading edge of the fog bank and the likely movement of the fog bank to the northeast are considered in the calculations, both of which would have obscured the button of runway 15 to an aircraft at an even higher altitude and/or closer distance. Therefore, it is concluded that the button referred to in this call was that of runway 33 or 27.

During the seven to eight minutes that elapsed from the time the Lear Jet landed until the accident aircraft was on downwind and base leg, it is likely that the fog bank moved from the position half-way down runway 15 to a position further to the northeast. This is supported by the reducing visibilities reported in the 0828, 0834, and 0840 PDT observations. Even if the fog bank did not move far enough during this time to obscure the threshold of runway 15 to an observer on the ground in the base leg area, the sloping leading edge of the bank could have obscured the threshold to the crew of the accident aircraft. Given the witness accounts of the weather, the calculations which indicate that the button call was not the button of runway 15, and the absence of any information on the CVR that would indicate that the crew had visual contact with runway 15, it is considered unlikely that the crew ever established visual contact with the landing runway.

2.4 Circling Approach Visual Requirements

The definition of "required visual references", which appears in both the Air Regulations and the AIP, is ambiguous. The ambiguity stems, in part, from the use of terms within the definition which, in themselves, are not defined or clearly understood by the aviation community. In addition, this ambiguity is compounded by the existence of a different definition in the CAP. Although a clearer description of the visual requirements for circling approaches is provided elsewhere in RAC 9.25 of the AIP and section 3.9.5 of

TP2076, the overall lack of a clear, concise definition consistent in all publications could result in misinterpretation by and confusion among pilots as to precisely what the visual requirements are for circling approaches.

As indicated in section 2.3, it appears that the crew proceeded past the MAP without establishing visual contact with the landing runway. In view of the lack of both clarity and consistency in the definitions of visual requirements for circling approaches, the crew of the accident aircraft may have continued with the approach based on a misunderstanding of the requirements.

2.5 CVR Analysis

2.5.1 Analysis Technique

For analysis purposes, that portion of the flight that was recorded on the CVR (0758:25 PDT to 0829:09 PDT) has been divided into four sections. The first covers the period from the start of the recording at 0758:25 PDT to the point when the crew commences the approach at 0821:08 PDT; the second from the commencement of the approach to the point when the aircraft crosses the TERRACE NDB at 0821:08 PDT; the third from the TERRACE NDB to the initiation of the missed approach at 0828:47 PDT; and the fourth from the initiation of the missed approach to the accident. The individual crew actions and conversations will be analysed in detail for each of these segments with reference to specific times of day determined from the CVR. Although individually each of these actions/conversations may not appear to have any significance, collectively they do indicate possible deficiencies in certain areas of human performance. Following analysis of these specific events, events which indicate similar human performance factors will be grouped to provide an analysis of each factor for the overall trip.

2.5.2 Period Prior to Commencement of the Approach

There were three comments made in the cockpit with regard to the weather conditions while the aircraft was en route to Terrace. These comments were made by the captain at 0804:46, 0809:44 and 0810:20 PDT. The nature of these comments indicates that, at this stage of the flight, the captain did not appear to be particularly worried about the Terrace weather and that he expected few problems in this regard.

At 0812:34 PDT the captain briefed the co-pilot on the approach into Terrace. Although the AFM does not detail an approach brief, the content of such a briefing is covered in the TC Instrument Procedures Manual TP2076, and the briefing given was deficient in many areas. In particular, the briefing did not include a complete description of the approach, the missed approach procedure, the status of the aircraft navigation aids, or the speeds to be flown. In addition, the MDA which was briefed was applicable to a Category C aircraft. This inadequate briefing could be associated with two areas of concern already discussed. The lack of company SOPs meant that there were no company standards governing when and how such a briefing would be given. The reduced training and check-ride standards applicable to ANO VII No.3 meant that the conduct of approaches in general, including the associated briefings, were checked less frequently and probably less vigorously.

On three occasions, the captain asked the co-pilot for information which had just been passed to them over the radio or for clarification of the situation. At 0816:26 PDT, the captain asked about the surface wind at Terrace even though this wind information had just been passed to them by the Terrace FSS. At 0820:10 PDT, the captain commented "What's going on?" just after the radio calls between the Lear Jet and the FSS regarding the Lear Jet's missed approach and between the accident aircraft and the FSS regarding the holding clearance. Finally, at 0820:25 PDT and 0820:33 PDT, the captain twice questioned whether the Lear Jet had landed even though the FSS had just indicated this when they had passed the approach clearance. In all three of these cases, the responses from the co-pilot indicated that he was fully aware of the situation. All these queries from the captain illustrate a certain confusion in the mind of the captain over the developing situation at Terrace and an inability to fully assimilate all the information being presented to him. In addition, the fact that the Lear Jet had missed the approach should have been enough to alert the crew to the fact that the weather might present a problem and prompted them to revise the approach briefing.

2.5.3 Period from the Commencement of the Approach to the TERRACE NDB

At 0822:00 PDT, the crew altered their intended landing runway from 33 to 15 based on information received from the FSS. The circling procedures for runway 15 are significantly different from those for 33, involving a turn through approximately 190 degrees, and yet there

was no additional briefing to cover this. Again this is an indication of inadequate training or a lack of standardization or both.

At 0822:13 PDT, the Lear Jet informed Flight 070 that there was a "hole" in the cloud over the localizer transmitter which would allow them to descend and land on runway 15. The crew of Flight 070 had not voiced any concerns or made any preparations which indicated that they had considered any possibilities other than landing at Terrace. This transmission from the crew of the Lear Jet would have reinforced the impression in the minds of the crew that, although the weather conditions were deteriorating, a successful landing was still expected. The fact that the crew still did not brief for the possibility of a missed approach also indicates that the crew was expecting to land.

This segment of the approach was poorly planned by the crew. They commenced the approach at 15,000 feet asl, and the aircraft was well above the published approach altitudes throughout this segment. Although these published altitudes are minimum altitudes, remarks made by the captain clearly indicate that he was aware that the aircraft was high. He attempted to rectify this problem by selecting three-quarter flap early and by lowering the landing gear at 6,800 feet, presumably to increase the drag and expedite the descent. As a result, throughout the approach, the captain was constantly trying to establish the aircraft on a more acceptable descent profile. He did not succeed in doing this as the aircraft crossed the TERRACE NDB at 3,050 feet rather than the published altitude of 2,200 feet. The crew could have easily avoided this problem by remaining in the holding pattern after being cleared for the approach and descending prior to commencing the approach to a more suitable altitude.

At some time prior to or during the approach, the crew should have conducted a passenger briefing; however, this was not done. Given the problems encountered by the Lear Jet and the potential for a diversion, it would be normal for the crew to brief the passengers on the possibilities. This again indicates that the crew was not considering the possibility of a diversion and was focusing solely on the approach and landing at Terrace.

2.5.4 Period from the TERRACE NDB to the Initiation of the Missed Approach

At 0825:59 PDT, the captain had to query the co-pilot about a radio transmission from the FSS regarding the approach light setting on runway 15, and again, at 0826:57 PDT, he asked what the reference speed was. In both cases, the co-pilot responded with the correct information, indicating he was aware of the situation. As discussed previously, this is another indication of a lack of awareness on the part of the captain.

There were three occasions during this segment, at 0826:17, 0827:16, and 0827:36 PDT, when the co-pilot uttered exclamations of surprise and concern. Although the weather conditions were not specifically mentioned in these comments, it appears that all three were associated with the co-pilot's perception of the weather conditions and that he perceived these conditions to be worse than he had anticipated. There was no response from the captain to any of these comments, and the co-pilot did not pursue them further. This indicates a lack of communication or coordination between the two crew members. If the co-pilot had been more forceful in presenting his concerns and/or the captain had been more receptive to these concerns, this might have prompted an evaluation of the situation and a better awareness of the circumstances.

At 0826:34, 0827:19, and 0827:33 PDT, the captain called visual contacts with the ground. The second visual call by the captain at 0827:19 PDT was "OK, I got the button here." This was approximately one minute and 50 seconds after crossing the TERRACE NDB and just after the aircraft reached MDA. Based on this timing, it is likely that the button referred to was the button of runway 33 or 27. Just after this visual call, at 0827:24 PDT, the captain cautioned the co-pilot to get ready to extend full flap. The captain was expecting to land and was making preparations to do so. There were no indications at this point that either crew member had the landing runway visual. The aircraft would have reached the published MAP at approximately the same time as the second visual call, so that it appears that the crew continued passed the published MAP without establishing visual contact with the landing runway.

At 0827:33 PDT, the captain called visual with runway 27, and, at 0828;00 PDT he said "OK, yours." The captain appeared to be saying this to himself as it did not evoke a response from the co-pilot. This occurred just after the aircraft crossed the localizer transmitter and appeared to be a commitment to begin to

descend for landing because, shortly after this, the aircraft began to descend and full flap was lowered. The aircraft position at this time was in the vicinity of the "hole" or clear area reported by the Lear Jet crew. It is likely this comment by the captain indicated that he had located this area, and that he subsequently descended through this area for landing. Once again there were no indications the landing runway was visual, and, in light of the other visual calls that had been made, it is logical to assume the crew would have called visual with the landing runway. If the crew did not have the landing runway visual, then the descent below MDA was not in accordance with either TP2076 or the AIP and would indicate poor airmanship and judgement on the part of the crew. In addition, the co-pilot should have forcefully questioned the captain's decision to descend in these circumstances. The actions of both crew members may have been influenced by a misunderstanding of what visual references were required.

Throughout the approach there were no indications on the CVR that the altitude alert system was being used.

2.5.5 Period Following the Initiation of the Missed Approach

In the AFM, the pilot flying is required to set the power during a balked landing procedure and to ensure that the engine limitations are not exceeded. It is possible that, despite the AFM procedure, the co-pilot tuned the engine power after the power levers were advanced by the captain. If this was not the case, the captain not only had to fly the aircraft and initiate the co-pilot's actions, but he also had to ensure that the engine operating limitations were not exceeded while he advanced the power. This would have been a significant distraction at a critical phase of flight and could have diverted or partially diverted the captain's attention from the task of flying the aircraft.

The missed approach procedure was not carried out in accordance with the procedure described at 1.17.11. First, there was no verbal indication on the CVR that a positive rate of climb was established prior to the gear-up selection. The primary indication of a positive rate of climb is an increasing altitude on the altimeter. The FDR indicates that the altitude began to increase six seconds after the initiation of the missed approach and four seconds after the gear-up call. Given the FDR indications, it is unlikely that the crew had established a positive rate of climb prior to the gear-up call. The second deviation from the correct procedure was a "flaps up" call by the captain

rather than a "flaps to one half" call. It is possible that the captain elected to give this call because the airspeed was such that the flaps could be safely retracted to the full-up position. However, the co-pilot's response to the flaps up call was "Flaps coming up to half." It appears that either the co-pilot was complying with the check-list despite the captain's command or had complied with the captain's command, but was indicating that the flaps were beginning to cycle toward the half position. Procedures such as this one have to be committed to memory because there is not sufficient time to consult a check-list during such a critical phase of flight, and these procedures should not be altered to suit the particular circumstances at the time. These deviations from the check-list procedure could be attributable to a number of things: first, the lack of a missed approach briefing meant that the crew was likely not mentally prepared for the procedure; second, the crew had not been required to demonstrate their proficiency in carrying out this procedure in simulated IFR conditions either during training or on check-rides; and third, there were no company SOPs to clearly define the actions required and the responsibilities of each crew member.

At 0828:49 PDT, the captain called "gear up" and then repeated this call three seconds later despite a clear acknowledgement by the co-pilot of "gear's coming up" between the two calls. This may indicate the captain was so occupied with flying the aircraft at this time that this acknowledgement did not register. In addition, as already discussed, the requirement for the captain to monitor the engine parameters at this same time may have been a distracting influence which caused him to miss the co-pilot's call.

There are continuous trim beeps recorded on the CVR from 0828:54 PDT to 0829:00 PDT (17 beeps) and from 0829:05 PDT until impact (7 beeps). As the trim beeps during both of these intervals are continuous, the trim input in the cockpit would have been continuously applied during each interval and would have been in the same direction throughout each interval. The first series of beeps commenced just following the gear-up calls by the captain and ended just prior to the first descending call by the co-pilot. This first series of beeps occurred in response to the power and configuration changes initiated during the first seven seconds of the missed approach. As all these changes would have produced a nose-up pitching moment, it is logical to assume that these 17 beeps were associated with a nose-down trim input. This assumption is supported by the FDR data which indicate an aircraft

pitch change appropriate to a nose-down control input and a vertical acceleration of slightly less than one "G". The second series of trim beeps began as the captain acknowledged the first descending call by the co-pilot. It is likely that, in response to this call, the captain began to apply nose-up trim. This is also supported by the FDR data which indicates increasing positive vertical acceleration during this interval. The fact that the aircraft appeared to have been in a nearly level attitude when it initially struck the trees also tends to support the fact that a nose-up control input was being applied.

During the last five seconds, the co-pilot twice informed the captain that the aircraft was descending. There was some indication of concern in the voice of the co-pilot in the first call, and this concern appeared to increase in the second call. Certainly, the second call was more emphatic than the first. The captain's response to the first call was a calm, level "OK". There is no indication in this response that the captain was aware of the gravity of the situation.

At the time of the first descending call, the aircraft was at an altitude of 940 feet asl, or approximately 160 feet above the tops of the trees, and descending at approximately 900 to 1,000 fpm. It is possible that a large, aggressively applied elevator input at this time might have prevented the aircraft from striking the trees; however, the captain did not do this and therefore was likely unaware of the developing situation. The only action on the part of the co-pilot at this time which might have prevented the accident would have been to seize control of the aircraft and apply the necessary elevator input. The co-pilot did not take this action and therefore was not fully aware of just how critical the situation was and/or was not assertive enough in reacting to the situation.

2.6 Human Performance Factors

2.6.1 Training/Supervision

On a number of occasions throughout the approach, there were examples of incorrect or inappropriate crew actions or procedures which could be attributed, at least in part, to inadequate training and/or supervision. These crew actions were as follows: the incomplete initial approach briefing and the failure to rebrief for the runway change; the poor approach planning with regard to the choice of an initial altitude; the selection of the wrong MDA; the failure to use the altitude alert system; and the incorrect

missed approach procedure. All the above are indications that not only was the crew training inadequate but that the on-going supervision of the crew's performance through check-rides and PPCs was also deficient.

The operator had received from TC, via a waiver, the authority to operate the Metro III in accordance with standards applicable to operations under ANO VII No.3 (small aircraft). As a result, Skylink's pilot training and monitoring requirements were less demanding than those which would have been required under ANO VII No. 2 (large aircraft). Specifically, the level of training which the pilots received and the frequency and content of their check-rides were all significantly below what would have been required had they been operating under ANO VII No.2. Perhaps the most significant aspect of operating under ANO VII No.3, as far as this accident is concerned, is the fact that the accident occurred during a missed approach in IFR conditions and the IFR training and check-ride requirements, although sufficient to meet the requirements of ANO VII No.3 were considerably below those required by ANO VII No.2.

2.6.2 Judgement

Flawed judgement was evident in many of the decisions made by the crew members. At the time of their departure from Vancouver, it would have been normal for the crew of the accident aircraft to expect to land at Terrace given the forecast weather conditions. As the trip progressed and it became apparent that the conditions were considerably worse than forecast, the crew's expectation to land should have lessened. There were a number of indications, however, that this was not the case: first, the comments made regarding the weather while the aircraft was en route did not indicate a concern over the deteriorating conditions; second, the passengers were never briefed on the possibility of not landing at Terrace; and third, the crew did not brief for the possibility of a missed approach. The crew did not fully consider the possible implications/effects of the rapidly changing weather conditions at Terrace despite the fact that there were ample indications from weather reports and from the actions of the Lear Jet crew that the weather conditions at Terrace had deteriorated significantly.

The actions of the crew during the approach were also indicative of poor judgement. The crew began the approach at 15,000 feet; the approach descent would have been less rushed and would not have required early configuration changes had the crew decided to descend prior to commencing the approach. More importantly,

however, it appears that the crew continued past the MAP, descended below MDA, and configured the aircraft for landing based not on visual acquisition of the landing runway, but on visual contacts with other areas of the aerodrome. It is possible that the judgement shown by the crew in the decisions made at the MAP and in descending below MDA was adversely affected by a misunderstanding of what visual references were required.

2.6.3 Fatigue

Having considered all facts surrounding and leading to this accident, as revealed in the contents of this report, we have attributed that there is no basis for a conclusion of the existence of fatigue in the aircrew.

2.6.4 Crew Procedures

2.6.4.1 Standard Operating Procedures

The information on operating procedures which was available to the crew was not adequate. This was evident from the procedural errors/omissions made by the crew, namely: the content of the approach briefing; the lack of a briefing following the runway change; the cockpit look-out procedures on approaching and reaching MDA; and the incorrect missed approach procedure. As there were no published company documents to cover these or other procedures, nor were any required by regulation, written guidelines or directions were not available to the crew. The absence of written procedures would be conducive to the use of different procedures by company pilots and, as was indicated during interviews with company pilots, confusion as to what procedures were in effect. Although such published standards would always be beneficial, they would be particularly so in a company like Skylink where pilots fly more than one aircraft type and there is a high turnover rate of supervisory personnel. SOPs are used extensively by most major air carriers on a voluntary basis because they feel that this document is a necessary part of a safe and consistent operation. The need for such a document on the smaller carriers is no less important.

SOPs can also be used to amend AFM procedures which are not deemed suitable for a particular operation. For example, in this case, the AFM missed approach procedure could have been changed by SOPs to indicate that the co-pilot was responsible for power management. This would have brought the procedure in line with accepted industry standards, relieved the captain of this responsibility at this critical stage of flight, and resulted in a safer procedure.

2.6.4.2 Crew Coordination

The coordination/communication between the two crew members was lacking at times and at other times non-existent, as evidenced by the following circumstances: the exclamations of concern about the weather by the co-pilot and the absence of any follow-up by either crew member; the descent below MDA without the runway visual and the acceptance of this descent by the co-pilot; the incorrect missed approach procedure; and the inadequate response from both crew members during the final descent to impact. Although a certain degree of crew coordination can be attained by simply flying with a particular individual, it is also essential that the crew receive the appropriate guidance through company standards such as SOPs and the appropriate training both in the air and on the ground.

Over the past few years, various airlines and aviation organizations have been training their pilots in an area which has come to be known as cockpit resource management (CRM). CRM is aimed at training pilots to make full and effective use of the human and other resources in the cockpit, thereby improving the ability of pilots to make appropriate decisions. CRM encourages pilots to be more receptive to the inputs of other crew members and more assertive in expressing their own concerns. Such training can be particularly effective in preparing crews to cope with emergency situations or unforeseen circumstances. Neither crew member of the accident aircraft had received any such training nor is any required by TC.

2.6.5 Distraction

The captain may have been distracted from his primary task of flying the aircraft during the missed approach procedure. The AFM requirement for the captain to set the power during the missed approach procedure provided a distracting influence at a critical stage of flight.

Another potential source of distraction and possibly confusion was the FD system in the accident aircraft. The crew had received no training on this system and had only flown with the system during the previous two days. The crew's flying in the past few months had been almost all on the other Metro III aircraft which was equipped with an AI which displayed roll attitude in a different manner from the FD. As a result, the crew would have been used to the AI roll display. There could have been a tendency for the captain to revert to the system with which he was most familiar, specifically the AI system, during the stressful and high workload circumstances of the missed approach.

This may have created confusion and thereby provided a distracting influence in addition to that associated with the requirement to monitor the engine parameters.

2.7 Systemic Deficiencies

The deficiencies identified at Section 2.5 can each be attributed, at least partly, to an inadequate availability of resources in the operation and monitoring of the company. The crew members were qualified and trained to the required standards and were by all accounts conscientious and capable, and yet these deficiencies were evident throughout the flight. There is every reason to believe that, had this crew been better trained, monitored and informed, the deficiencies noted would have been reduced or eliminated. Although none of these deficiencies can be shown to be causal, each tends to degrade the overall performance of the crew and in particular to degrade the ability of the crew to cope with infrequently encountered high-workload situations such as a missed approach in IFR conditions.

2.8 Disorientation

2.8.1 General

The time from the initiation of the missed approach to the disruption of electrical power to the CVR was 22 seconds. The captain's perception of what the aircraft was doing and his reactions to these perceptions during this period are critical to the understanding of this accident. The vertical profile of the aircraft as determined from the FDR and the calculated perceived pitch attitude as shown at Appendix E will be used to analyse this period. It is assumed in this analysis that the crew had no external visual cues throughout this period and that the aircraft pitch attitude as determined from the simulator is representative of the aircraft pitch attitude during the missed approach sequence. For the sake of clarity, time zero in this discussion will be the "In the missed" call and everything will be referenced to this time. This 22-second period will be divided into three intervals for analysis purposes: interval one - from zero to four seconds; interval two - from four to 12 seconds; and interval three - from 12 to 22 seconds.

2.8.2 Interval One

From time zero to time four seconds, the aircraft pitch attitude and the perceived pitch attitude were essentially the same, indicating that the captain's perception of pitch attitude, based solely on his vestibular senses, was generally correct. This is supported by the fact that the captain's actions and the aircraft motion during this period were consistent with what would be expected in these circumstances. There were only minor variations in aircraft speed, altitude, and vertical acceleration.

2.8.3 Interval Two

From time 4 to time 12 seconds, the perceived and actual pitches are similar; however, they slowly diverge over this period until they differ by two to three degrees at time 12 seconds. The aircraft begins to climb at time five seconds and continues to climb for the remainder of this interval. At the end of the interval, however, the rate of climb has reduced to almost zero. The aircraft pitch reaches a maximum nose-up value of five degrees at time nine seconds and then decreases to zero degrees at time 12 seconds. The captain begins to trim nose-down at time seven seconds in response to the nose-up pitch resulting from the power and configuration changes and continues to trim nose-down for the remainder of the interval. The aircraft had accelerated approximately five knots during this interval.

The captain perceived correctly that the aircraft was climbing during this interval; however, it appears that he was unaware that the aircraft pitch was decreasing towards zero during the last few seconds of the interval because he continued to apply nose-down trim. Even when the aircraft pitch had decreased to zero at time 12 seconds, he continued to trim nose-down. It is possible that the application of pitch by the captain during the last few seconds of this interval was based, at least partly, on a misperception of pitch attitude resulting from the aircraft acceleration during the previous seven seconds.

2.8.4 Interval Three

Throughout this interval, from time 12 to time 22 seconds, the captain perceived that the aircraft was in a nose-up attitude, when in reality the aircraft was pitched nose-down and descending. During the first six seconds of the interval, the perceived pitch and the actual pitch diverge until a maximum difference of 13 degrees is reached at time 18 seconds. Although this

difference decreases to approximately 10 degrees during the last four seconds of flight, this is a result of changes in aircraft pitch; the perceived pitch remains constant at five to six degrees nose-up. These differences in perceived and aircraft pitch indicate that the captain was experiencing the effects of a somatogravic illusion during this interval and that his perception of pitch could have been incorrect by as much as 13 degrees.

As was indicated in the factual section, significant errors in perceived pitch attitude can occur within a few seconds of a change in force environment. There were two force changes which occurred just prior to this interval to cause these errors in perception. First, the aircraft had been accelerating in a forward direction for approximately seven seconds prior to this interval as a result of the increase in power and the decrease in drag from the configuration changes. Second, the change in aircraft pitch attitude from five degrees nose-up at time eight seconds to zero degrees at time 12 seconds as a result of pitch trim and/or elevator inputs resulted in an even greater overall aircraft acceleration than would normally be encountered during a missed approach. The initial acceleration would have created and then sustained the illusion, and the acceleration from the nose-down pitch change would have amplified as well as sustained the illusion.

The nose-down trimming stops one second into this interval; however, as was determined in the simulator trials, this was approximately equivalent to full nose-down trim, and therefore, the trimming may have stopped because the nose-down limit was reached. The other possibility is that the captain stopped applying nose-down trim because he perceived that the aircraft pitch attitude was now at only two to three degrees nose-up and he did not want to reduce the pitch attitude any further. No matter which of these circumstances is correct, for the five-second period following the application of nose-down trim, the aircraft pitch attitude decreased and the aircraft began to descend, and there were no apparent pitch control inputs to arrest this descent.

The only apparent nose-up control input came following the first descending call by the co-pilot at time 17 seconds. One second after this call, the trim was applied, presumably in a nose-up direction, and judging by the rapid increase in the aircraft vertical acceleration, the captain was also applying nose-up elevator. At this point, the captain still perceived that the aircraft was at a pitch attitude of

approximately three degrees nose-up, so that his control inputs were now most likely in response to the call from the co-pilot rather than to his perception of pitch. The co-pilot's reaction to the descent of the aircraft indicated that, although he also may have been suffering from the effects of this illusion, he was aware of the actual flight circumstances, presumably through his instruments. This is particularly evident as the descending call came only two seconds after the aircraft had begun to descend. As stated at 1.17.12.1, there are large individual differences in the magnitude of this illusion, and therefore, it is probable that the co-pilot was much less affected by this illusion than the captain and was therefore able to quickly discern the descent.

2.8.5 Effect of Roll Attitude

The analysis of illusions thus far has dealt only with misperceptions of pitch attitude and has assumed that the aircraft was wings-level throughout the missed approach procedure. However, the aircraft could have been at other than a wings-level attitude for a number of reasons. The published missed approach procedure calls for an immediate climbing left turn, and the captain may have initiated this turn. There is also the possibility that the captain may have experienced a somatogyral illusion. It is likely that the aircraft was still turning left when the missed approach was initiated, as the heading was likely still some 20 to 30 degrees south of runway heading. If the captain had quickly rolled wings-level at this time, he may have induced a somatogyral illusion. Any illusory effects of this nature could have been compounded by confusion as to the roll attitude caused by the unfamiliarity with the FD system. The simulator trials demonstrated that bank angles from zero to 45 degrees were possible during the missed approach without any substantial differences in the time taken from missed approach initiation to impact, and that these times were all within a few seconds of this same time period recorded on the CVR. If there was bank on the aircraft during the missed approach, this may have aggravated any perceptual problems that the captain was experiencing, but it would not have significantly affected the accident sequence.

2.8.6 Spatial Disorientation Sequence

As a result of the acceleration and pitch changes of the aircraft which occurred during the initial 12 seconds of the missed approach procedure, the captain likely experienced a somatogravic illusion which resulted in a significant difference between the pitch

attitude which he perceived and that of the aircraft. The captain applied pitch trim and possibly elevator based probably on his perception of the aircraft pitch which resulted in a descent toward the terrain. The descent was recognized by the co-pilot, and corrections were made by the captain to arrest the descent; however, these control inputs were not sufficient to prevent the aircraft from striking the trees. The captain may have also experienced a somatogyral illusion in that he may have perceived a roll attitude which was different from that of the aircraft; however this could not be confirmed.

2.9 Other Safety Issues

2.9.1 FDR Requirements

Three areas of concern with respect to the FDR were discovered during the investigation. First, the heading parameter was not functioning; second, there was no documentation on the calibration and maintenance of the recorder; and third, a waiver was not granted to permit the use of a foil recorder in lieu of a digital recorder. It appears that TC overlooked the requirements of ANO Series II No.13 during the importation and certification inspections of the aircraft and that the operator did not comply with the FDR requirements of the ANO or the Engineering and Inspection Manual. Had the required procedures been followed, it is likely that the unserviceable heading function would have been discovered, and a more complete analysis could have been made of the accident flight.

2.9.2 Airport Disaster Plan

The implementation of the Airport Disaster Plan was hampered by the heavy fog which created problems in locating the crash site. Despite this, the crash site was located within 24 minutes and the fire was brought quickly under control. There were problems associated with the initial dispatch of the ambulance service and with the coordination of the ambulances after they were dispatched, which resulted in ambulance services not being available at the site until 45 minutes after the accident. Although the delay in the arrival of the ambulances was not of any consequence in this accident, such a delay in different circumstances could be a major factor in the survivability of aircraft occupants.

2.9.3 TC Company Audits

The audits conducted in September 1987, June 1988, and September 1989 all resulted in OC suspensions and/or cancellations, and all three suspensions/cancellations were for similar reasons. For the first two suspensions, the OC was reinstated based on accounts from the company of corrective action taken; there did not appear to be any additional "on-site" inspections to verify or ensure that the corrective actions had indeed been implemented prior to reinstatement of the OC. The fact that similar reasons for suspension were discovered in all three audits indicates that whatever corrective action was implemented was not continued or was not adequate and that TC procedures for follow-up monitoring and surveillance of company operations were not effective in ensuring that the company maintained the required standards.

3.0 CONCLUSIONS

3.1 Findings

1. The aircraft was certified in accordance with existing regulations and approved procedures.

2. The aircraft weight was within the prescribed limits.

3. The position of the aircraft C of G could not be determined.

4. There were no TC or company requirements to maintain a copy of the weight and balance form at the dispatch location.

5. A five-parameter foil FDR was installed on the aircraft. ANO Series II No.13 and TC policy documents require a six-parameter digital FDR.

6. Calibration and maintenance information on the FDR was not available. This information was required by ANO Series II No.13 and the Engineering and Inspection Manual.

7. The left clutch in the stick pusher servo of the SAS had not been removed as required by the applicable AD.

8. There was no evidence found of any airframe failure or system malfunction prior to or during the flight.

9. Scheduled passenger flights were operating to and from Terrace at times outside the CFR hours of operation.

10. The BC Ambulance Service dispatch at Kamloops was not notified of the accident as was required by the Airport Disaster Plan.

11. Coordination problems resulted in the ambulances arriving at the accident site 32 minutes after Kamloops dispatch had been notified.

12. The company had been granted a waiver to operate the Metro III aircraft under ANO Series VII No.3 which resulted in lower operating standards than normally required for large aircraft operations.

13. The flight crew was certified and qualified for the flight in accordance with existing regulations.

14. There was no evidence that incapacitation affected the crew's performance.

15. Company operating procedures did not adequately cover all aspects of the company's flight operations.

16. The crew did not fully consider the possible implications/effects of the rapidly changing weather conditions at Terrace.

17. The crew selected the wrong MDA for their aircraft category.

18. The captain continued past the published MAP, descended below MDA and configured the aircraft for landing without the required visual references.

19. The co-pilot did not question the captain's actions to continue the approach without the required visual references.

20. The TC definitions and descriptions detailing the visual references required to carry out a circling approach are ambiguous and open to misinterpretation.

21. The crew may have misunderstood the visual references that were required to enable them to conduct the circling approach.

22. The requirement to monitor the engine parameters and the unfamiliarity with the FD were potential sources of distraction during the missed approach procedure.

23. The captain may have become disoriented during the missed approach procedure as a result of a somatogravic illusion.

24. The captain applied/maintained inappropriate control inputs which resulted in the aircraft descending to impact.

25. The co-pilot, although aware of the descent, was not fully aware of the proximity of the terrain or was not assertive enough in his actions to arrest the descent.

3.2 Causes

The crew continued with the approach beyond the missed approach point without establishing the required visual references. The evidence indicates that, while subsequently carrying out a missed approach in IFR conditions, the aircraft was flown into the ground in a manner consistent with disorientation. Contributing to the occurrence were the inadequacy of the company's operating procedures, the reduced operating standards, and the inadequate definition of the visual references required for a circling approach.

4.0 SAFETY ACTION

4.0.1 General

The crew's inability to execute a missed approach safely at low altitude was due to an incorrect perception of the aircraft's situation. This misperception resulted from deficient cockpit coordination and procedures, a non-standard approach procedure, weak CRM, inadequate monitoring of cockpit instrument indications, and inadequate control of the aircraft's attitude. In addition, the crew was not trained on some aircraft systems; if properly used, the flight director, altitude alerter, and radar altimeter may have helped to avoid this accident. All these deficiencies call into question the type and quality of training available to the pilots, the adequacy of company operating procedures, the regulatory proficiency standards required to qualify them for their crew positions, and the verification procedures used to determine their individual piloting proficiency.

Both pilots held valid type ratings and instrument endorsements, and they had received the training specified in the company OM, which had been approved by TC. Notwithstanding, neither crew member had received any formal CRM or simulator training, nor was there any indication that either pilot had received training or checking on circling approaches or in the low-altitude missed-approach procedure that they were attempting.

4.1 Action Taken

4.1.1 Commuter-Category Airplanes Commercial Operations

In accordance with TC Policy, Skylink had been granted a waiver to ANO Series VII No.2, Large Aircraft Order, to operate its Metro III aircraft under the less-restrictive ANO Series VII No. 3, Small Aircraft Order. This policy resulted in financial advantages to the company, which were realized from less-stringent flight attendant and flight data recorder requirements; however, it also meant less-demanding requirements for crew training, certification and monitoring, which created potential safety problems. Recognizing these deficiencies, TC subsequently rescinded its policy of issuing blanket waivers to ANO Series VII No.2 on 12 January 1990. This new policy no longer permits the operation of commuter-category aircraft under the Small Aircraft Order. Crews flying these aircraft are now

required to meet the more comprehensive training and certification standards of the Large Aircraft Order.

4.1.2 Canada Flight Supplement (CFS) - Terrace Listing

During the investigation, it was observed that the CFS did not list the KITIMAT NDB in the navigation facility block for Terrace. According to the criteria specified in the General Section of the CFS, navigation aids that serve as approach aids to the airport in question should be listed.

Because the KITIMAT NDB is used as an approach aid for all NDB approaches to the Terrace airport, a CASB Aviation Safety Advisory was sent to TC on 16 January 1990. The KITIMAT NDB is now listed in the NAV block for Terrace.

4.2 Action Required

4.2.1 Training and Checking Requirements for Pilots Conducting Passenger-Carrying IFR Operations

An analysis of Canadian aviation occurrence files involving multi-engine passenger-carrying aircraft operating under ANO Series VII No.3 revealed that, since 1977, there have been 15 accidents involving controlled flight into terrain, resulting in 75 deaths. Although these aircraft, which were in instrument meteorological conditions, were all found to be capable of sustaining safe flight, the pilots involved did not take the necessary action to prevent their aircraft from striking the ground, as in this Metro III crash.

ANO Series VII No.3 does not specify any particular instrument-flying standards for commercial operations. A single-level instrument rating standard, specified in the Personnel Licensing Handbook (PLH), is in effect for both private and commercial pilots. ANO Series VII No.3 and the PLH only require one annual instrument proficiency check, and this check need not be conducted in instrument conditions, simulated, or actual.

Corresponding United States regulations governing small aircraft operations dictate that American commercial pilots flying passengers must undergo check-rides every six months, and these regulations also specify a much more comprehensive list of requirements, all of which must be conducted in either actual or simulated instrument flight conditions.

Schedule C of ANO Series VII No.2 provides more-specific requirements, including a provision for conducting many flight manoeuvres under actual or simulated instrument conditions. However, evidence gathered during this investigation suggests that, when actual instrument conditions do not exist, because of flight safety concerns about the risk of collisions, TC inspectors are reluctant to establish a cockpit environment to simulate instrument conditions. The Flight Test Guide for Instrument Rating (TP 9939E) states that the air carrier company is to provide a method for simulating instrument conditions, but this requirement is rarely filled. Consequently, without a policy or guideline to help resolve the dilemma between the safety considerations of restricting cockpit visibilities and the specific ANO Series VII requirement to do so, the inspectors rarely, if ever, try to simulate instrument conditions. Therefore, although pilots conducting passenger-carrying operations in large aircraft are required by ANO Series VII No.2 to demonstrate their abilities under actual or simulated instrument conditions, they may not have to do so when actual instrument conditions do not exist during their check flight.

In the light of the 15 multi-engined aircraft accidents involving controlled flight into terrain, the TSB believes that the Canadian licensing, certification, and checking regulations covering operations under ANO Series VII may be deficient in that they do not ensure an adequate level of instrument flying proficiency. Since pilots involved in commercial passenger-carrying operations may, therefore, lack the requisite instrument flying proficiency, the safety of their fare-paying passengers may be compromised. Therefore, the TSB recommends that:

> The Department of Transport strengthen the requirements of ANO Series VII No.3 to better ensure that pilots engaged in commercial passenger-carrying IFR operations possess and maintain the necessary levels of instrument flying proficiency; and
>
> CTAISB A90-91
>
> The Department of Transport require all pilots engaged in commercial passenger-carrying IFR operations to demonstrate their instrument-flying proficiency to flight examiners under actual or simulated instrument conditions.
>
> CTAISB A90-92

4.2.2 FDR Approval Process

According to the Flight Data Recorder Order ANO Series II No.13 and a TC waiver policy on FDRs, the METRO III should have been equipped with a six-parameter digital FDR. In addition, ANO Series II No.13 and the Engineering and Inspection Manual (Part II Section 3.9) require the existence of FDR calibration and correlation documentation and a company maintenance plan for each FDR installation.

Ensuring that an appropriate FDR was installed should have been part of the TC approval process for the operation of this aircraft under the company's OC. This should have been done using TC Form 26-0046, which includes FDR availability as a check-off item for the TC Regional Air Carrier submission to TC Headquarters. Since this form does not include a specific provision for designating the type of FDR, the unauthorized FDR was not detected by the TC officials certifying the aircraft.

Ensuring that the FDR met the airworthiness installation and functional requirements should also have been part of the TC approval process for the aircraft's C of A. Normally, this should have been done when the initial type approval was done, based on the calibration data provided by the manufacturer. However, an imported aircraft's FDR is considered a follow-on installation; therefore, before a Canadian C of A for this aircraft was issued, the company should have been required to provide TC with the FDR calibration and correlation data, along with proof of the proper operation of the FDR and the existence of a company maintenance plan.

For the accident aircraft, a proper-type FDR was not installed, the calibration data was not provided to TC, the company did not have an FDR maintenance plan, and neither the company nor TC verified the proper operation of the installed FDR. FDR orders and standards exist to provide important information concerning flight characteristics for accident investigations and subsequent accident prevention. The absence of FDR heading information for this occurrence precluded an accurate determination of the flight path during the final minutes of flight; also, the lack of correlation data significantly complicated the precise determination of the remaining four parameters. Thus, the ability to identify safety deficiencies was hampered.

The anomalies noted in the approval process for this FDR installation may be an isolated case. Nevertheless, the TSB believes that the TC approval process for OCs and C of As is not adequate to ensure proper compliance with existing FDR ANO and Engineering and Inspection Manual requirements. That there are still a number of foil-type FDRs being used in Canada is of particular concern. Accident investigation experience indicates that, because of difficulties in maintaining and verifying the operation of foil FDRs, the reliability of these systems is at best uncertain. Therefore, TSB recommends that:

> The Department of Transport validate its approval process for FDRs to ensure that current procedures are adequate to meet the ANO and Engineering and Inspection Manual requirements; and
>
> CTAISB A90-93
>
> The Department of Transport ensure that the appropriate FDR correlation data is available for all installed FDRs and that companies have adequate maintenance plans and procedures for ensuring the continued serviceability of these FDRs.
>
> CTAISB A90-94

4.2.3 Aircraft Load Documentation

Internationally, it is common practice for an air carrier to maintain a copy of an aircraft's flight manifest with its operational dispatch authority. There is not a Canadian regulatory requirement to do so. ANO Series V No.4 requires that a flight plan contain only the number of persons on board the aircraft. For commercial aeroplane operations, this basic requirement is supplemented by requirements in ANO Series VII for the air carrier's OM to contain the methods and procedures for maintaining the aeroplane weight and C of G within approved limits; in addition, the Air Carrier Inspection Manual (TP 3783) requires that the company OM contain information on the use of the company's weight and balance form.

Notwithstanding the lack of regulatory requirements, most Canadian companies do maintain a copy of their passenger lists and aircraft load manifests in their dispatch centres. Also, the respective pilots or other designated company officials do a C of G calculation before each flight. However, it is not a common practice for smaller companies to maintain a copy of this latter documentation with the dispatch authorities; such was the case for this occurrence.

Knowledge of the aircraft's C of G is essential for an investigator to assess accurately the flight characteristics of the aircraft, an evaluation upon which many other areas of the investigation may hinge. Therefore, United States Federal Aviation Regulations (FAR) for multi-engine operations specifically require the preparation of duplicate flight manifests for each take-off, including the total weight and C of G; one copy is for the pilot, and one copy is to be maintained at the operations base.

In this occurrence, the only record of the passenger-seating arrangement and the precise distribution of the baggage and other cargo was carried on board the aircraft and was destroyed in the crash. As a result, it was impossible to confidently determine where the C of G was at the time of the crash. The TSB believes that the absence of formal documentation about an aircraft's weight and C of G can unnecessarily hamper the accident investigation process and hinder the timely identification of safety deficiencies. Therefore the TSB recommends that:

> The Department of Transport require that a copy of the aircraft's load distribution and centre of gravity calculations be retained on the ground by a responsible person for each flight of an aircraft engaged in commercial operations.
>
> CTAISB A90-95

4.2.4 Company Operating Procedures

This crew was licensed in accordance with the prescribed regulatory standards; however, there were a number of events throughout the flight which indicated that the crew's practices were not completely in accordance with both regulated and commonly accepted aviation industry norms. Within the company, employees expressed concern about the lack of consistent procedural standards, and there was confusion about which policies were in effect. In particular, pilots indicated that company policy would change depending on the circumstances, and they would often get different direction from the various levels of authority within the company. The lack of consistent policy and incomplete guidance apparently hampered the pilots' abilities to make sound decisions.

The source document used for determining flight procedures is the AFM provided by the manufacturer. This document lists the basic flight characteristics of the aircraft and provides only those performance data and those check-lists for the operational procedures

which are prescribed by type-certification regulations. However, missing from this source document are many basic flight procedures, cockpit procedures, crew responsibilities, and check-list items which are required in the different operational environments and by the aviation regulations governing the type of operation being conducted by the company.

To partially fill this gap, current regulations in Canada require air carriers to have a TC approved OM, which contains company procedures required both to ensure adequate management and control of the company's fleet-wide operation, and to ensure the adherence of company personnel to regulatory requirements. Except for a section within this manual designated to cover in-flight procedures and restrictions pertaining to adverse conditions, there is no requirement to specify routine flight procedures applicable to the individual aircraft types, or to specify the conduct of the in-flight responsibilities by the crews. Consequently, such additional direction to pilots was not available in this company's OM.

To bridge the remaining information gap between the AFM and actual operations, major air carriers (and also the Department of Transport Flight Services Directorate) publish SOPs. Such SOPs amend or amplify the information contained in the AFM, specify in-flight procedures for each aspect of company operation not covered in the AFM or the company's OM, and direct crew duties, crew cooperation, and CRM practices for normal and abnormal situations. Although not a regulatory requirement, SOPs are used extensively by major carriers because they believe that this type of document is a necessary part of a consistent and safe operation: SOPs establish management's expected standards and direct those aspects of in-flight operations vital to the goals of the company; these procedures can also be used as criteria to evaluate the effectiveness of the company's flight operation; SOPs form the basis for pilots to make sound and consistent decisions and to evaluate their individual performance against the company's standards and goals; and, documented SOPs tend to discourage ad-hoc management input to flight operations, which might impose unwarranted, adverse pressures on pilot decision-making.

SOPs are particularly effective in companies where either the pilot staff is large, the operation locations are dispersed, the types of operations and environment are diverse or non-standard, many aircraft types are flown, crew assignments change frequently, pilot and management turnover is significant, or pilot

and management ability is less than ideal. The presence of many of these factors is characteristic of the smaller airlines in Canada.

In summary, there is an information gap between the limited scope of the data in the AFM and the specific direction and guidelines required by flight crews to ensure a consistent and safe operation. Although TC requires a company OM, the criteria and guidance for the creation of this document do not adequately address in-flight operations. In this occurrence, the lack of procedural direction and guidance was evident in the crew's performance deficiencies which led up to the accident. The TSB believes that a comprehensive set of company SOPs addressing the standards, practices, and procedures is required to ensure consistent direction to management and flight crews for the conduct of safe air carrier service. Therefore, TSB recommends that:

> The Department of Transport require all air carriers to publish standard operating procedures to cover the conduct of all their in-flight operations; and
>
> CTAISB A90-96
>
> The Department of Transport establish guidelines for air carriers for the preparation of standard operating procedures, including those practices inherent in sound cockpit resource management.
>
> CTAISB A90-97

4.2.5 Circling Approach Visual Requirements

The description of the visual references required by a pilot conducting an approach procedure in Canada is contained in the Air Regulations and its enabled document, the CAP. However, the definition of the term "Required Visual Reference" in both documents is somewhat vague and open to individual interpretation, in particular when applying this definition to circling approaches. First, the elements that constitute the required visual reference are not specified; second, there are no definitions for the two key terms of "approach area" and "nominal flight path" used in the definition; and third, the visibility criteria used in the approach minima block are advisory only and not limiting.

According to Transport Canada Instrument Procedures Manual (TP2076), the visual manoeuvring area for a circling approach is determined using circles centred on the runway thresholds and with radii related to the

aircraft performance categories, in effect implying that prevailing visibilities at or above the visibility limits specified for the circling approach would be required to complete the circling approach procedure. Supporting this assessment are the statements in TP2076 and the AIP that the basic requirements for a circling approach are to keep the runway in sight and to remain at MDA until a normal landing is assured.

The International Civil Aviation Organization (ICAO) recommended operational procedures on visual requirements for circling approaches, which are much more explicit, are contained in ICAO Volume 1, Flight Procedures. Section 4.5 specifies that a descent below MDA should not be made until a visual reference has been established and can be maintained, and the pilot has the landing threshold in sight; and Section 4.6 defines the runway environment to be the runway threshold, approach lighting, or other markings.

United States FAR 91.116 (c) is even more explicit in stating that no pilot may operate an aircraft at any airport below the MDA unless at least one of the following visual references for the intended runway is distinctly visible and identifiable to the pilot: the approach lighting system, the threshold, the threshold markings, threshold lights, the runway-end identifier lights, the visual-approach slope indicator, the touchdown zone or touchdown zone markings, the touchdown zone lights, the runway or runway markings, the runway lights. FAR 91.116 also requires that the flight visibility be at least the visibility prescribed for the instrument approach procedure.

The TSB believes that the ambiguous nature of the current definition of "required visual references" in the CAP and the advisory nature of the approach visibility criteria are deficient in that they allow the interpretation that any visual contact with the airport environment could be deemed as acceptable visual reference for continuing the circling approach, even if visual contact with the runway has not been achieved. In addition, not specifying the elements of the approach area of a runway and not defining a nominal flight path allow for the interpretation that during a circling approach a descent below MDA can be conducted at any time after visual contact is made with the airport environment. Therefore, the TSB recommends that:

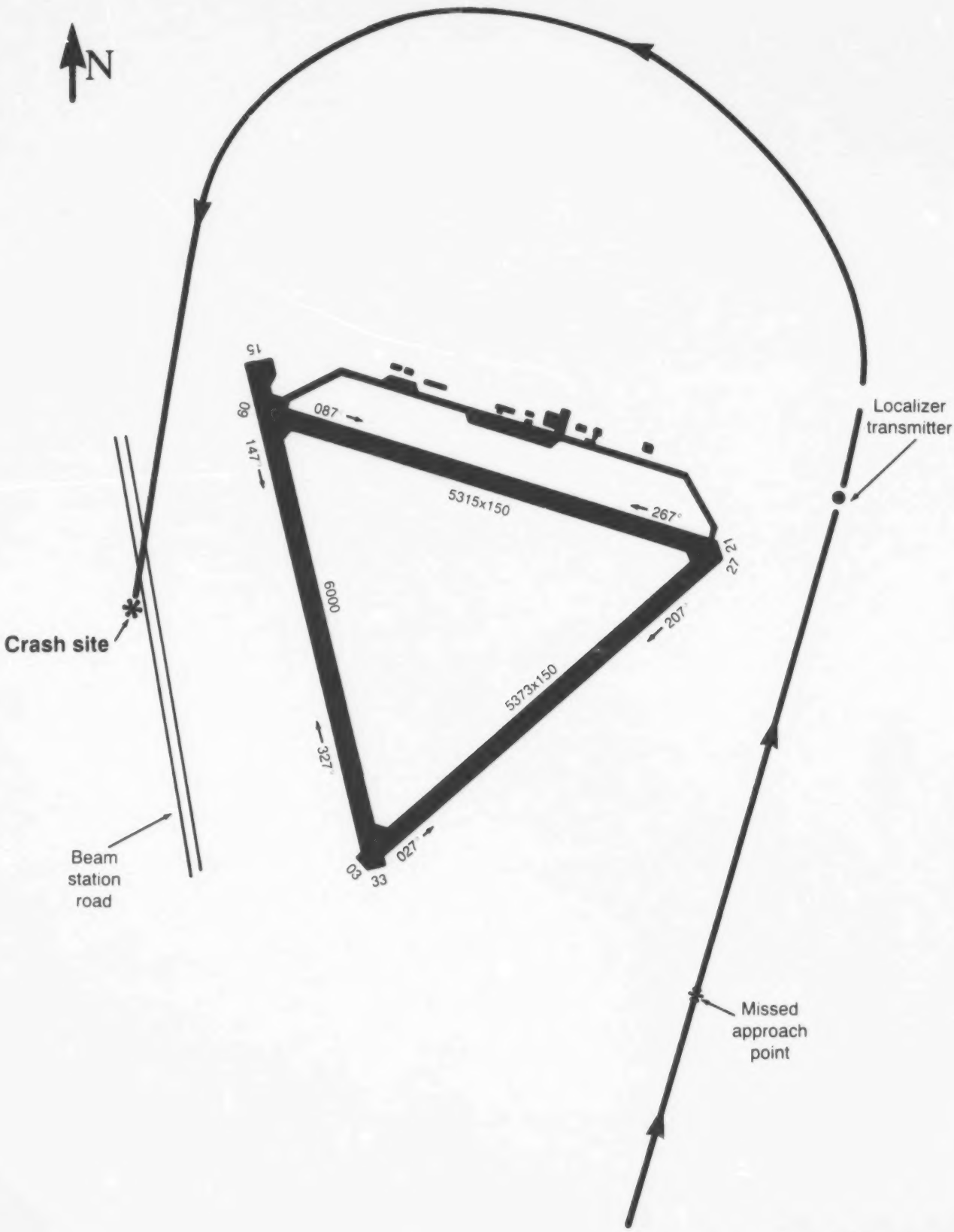
The Department of Transport modify its published references regarding the visual requirements for conducting circling approaches to ensure that they are clear and consistent with the internationally accepted norms, and adequately specific to minimize the chances of misinterpretation by pilots.

CTAISB 90-98

This report and the safety action therein has been adopted by the Chairman, J.W. Stants, and Board Members:

G.E. Bennett
Z.M. Brunet
W.R. Dupont
H.M. NacNeil

PLAN VIEW OF FLIGHT PATH



LDA/DME C

D.E M.&R. TERRACE BRITISH COLUMBIA

TERRACE

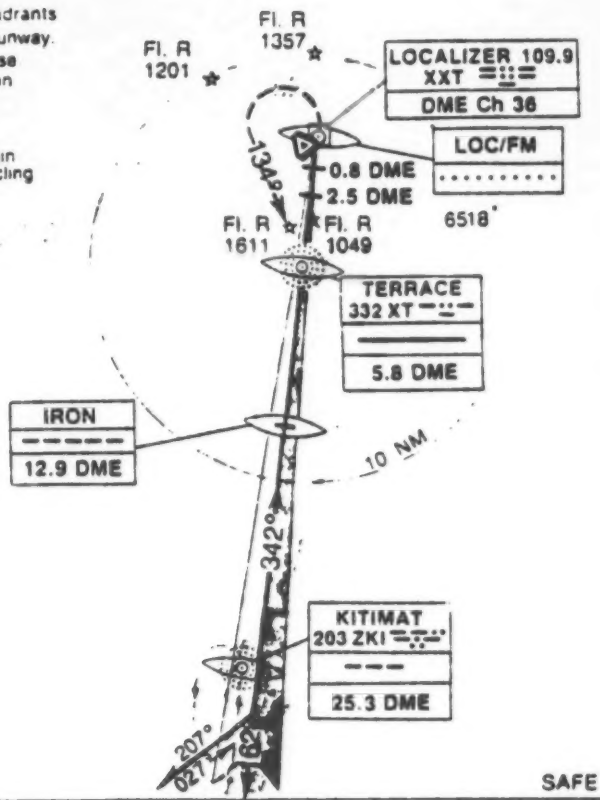
ARR	RADIO	DEP	ELEV
VANCOUVER CENTRE 128.4 269.1	122.0 (MF 5NM) 239.8	VANCOUVER CENTRE 128.4 269.1	713

CYXT

LOC ONLY
NO GLIDE PATH

Valley approach
Mountainous terrain all quadrants
Localizer not aligned with runway.
Airport left of localizer course
Localizer reliable only within 10° of centreline on either side.

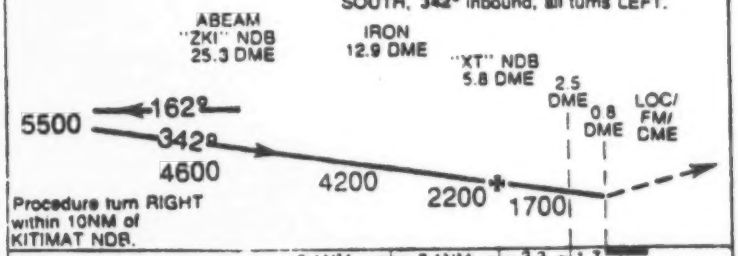
* Cat A, B, C aircraft remain within 2.7 DME while circling southwest of airport



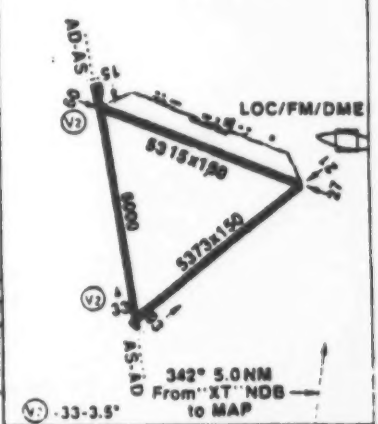
SAFE ALT 100 NM 11,100

Shuttle to 5500 within 10NM

MISSED APPROACH
At 0.8 DME climb to LOC/FM then immediate climbing LEFT turn intercept track 134° to "XT" NDB. Continue climb SOUTHBOUND on localizer to "ZKI" NDB at 5500. Hold SOUTH, 342° inbound, all turns LEFT.



Right hand circuits Rwy 33



CATEGORY	A	B	C	D
* CIRCLING	1240 (527) 1½		1240 (527) 2	1600 (887) 2½

"XT" NDB to MAP 5.0NM

Knots	70	90	110	130	150
Min Sec	4:17	3:20	2:44	2:18	2:00

LDA/DME C

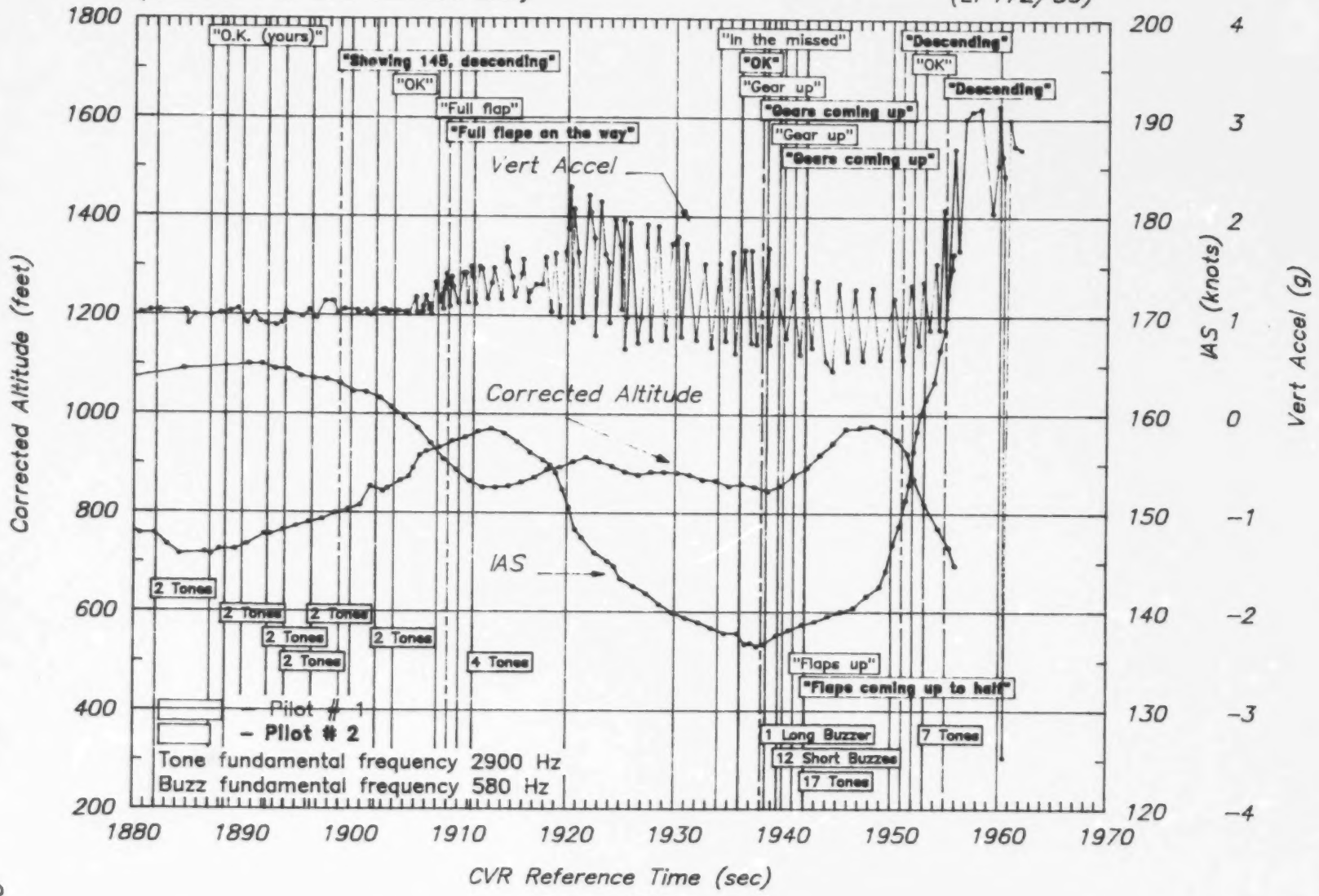
N54 26 00 W129 34 33 VAR 25°E

TERRACE BRITISH COLUMBIA
TERRACE

CHANGE: Hazard Beacons

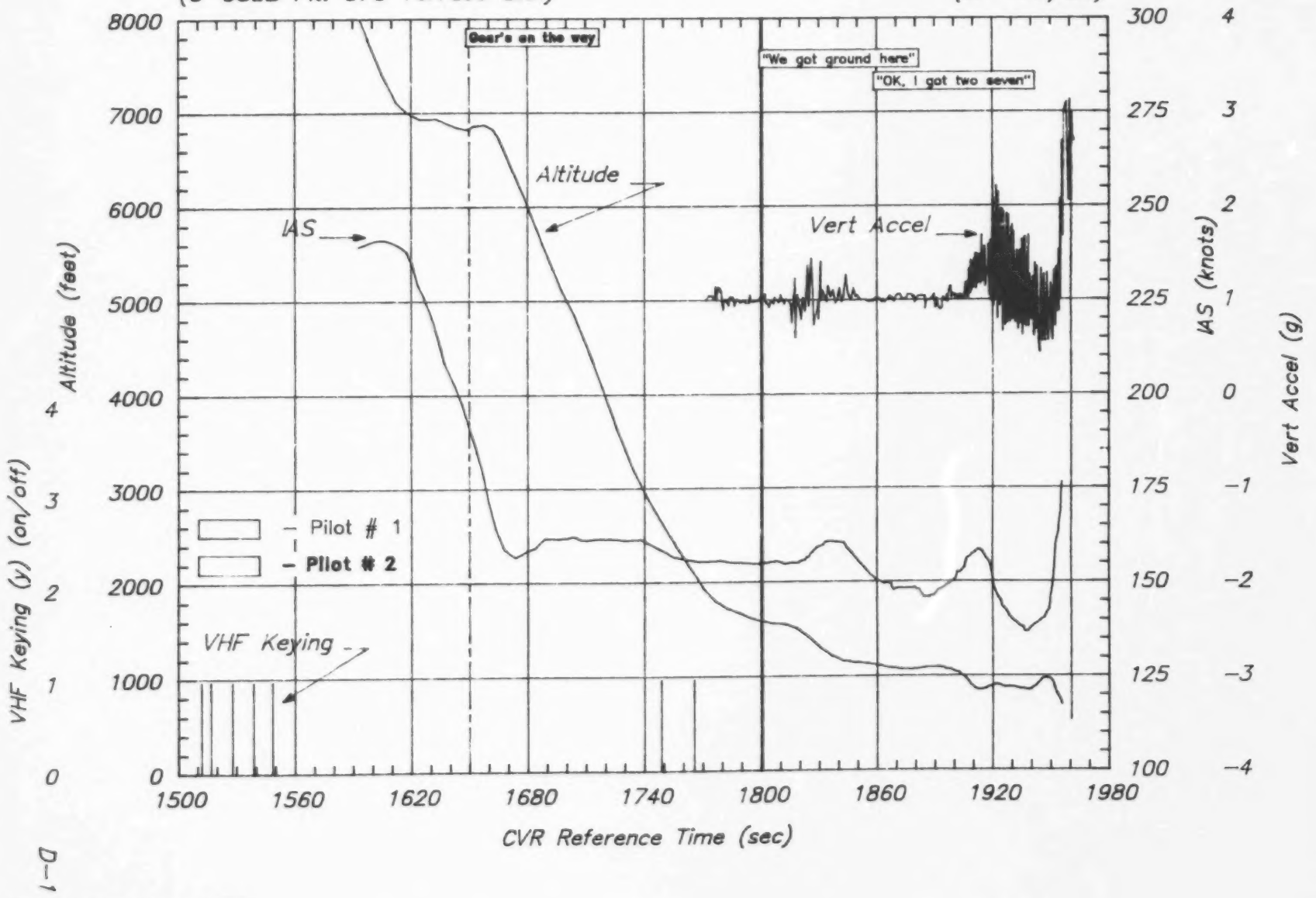
Alt. / IAS / Vert. Accel. Vs CVR Time

(C-GSLB Flt. 070 Terrace B.C.) (LP172/89)



Alt / IAS / Vert Accel / VHF Key Vs CVR Time

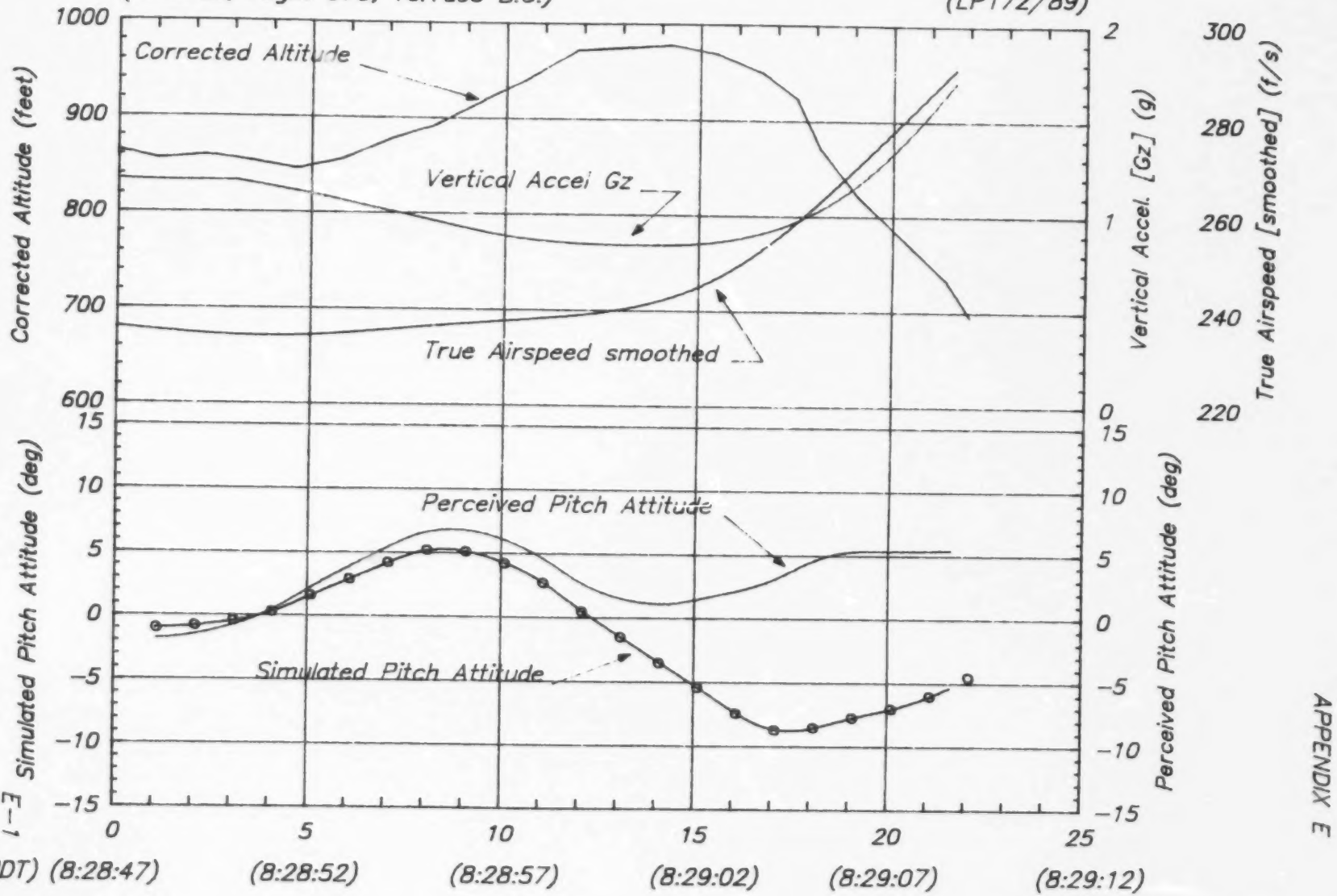
(C-GSLB Flt. 070 Terrace B.C.) (LP 172/89)



Plotted: 7 May, 1990

Perceived Pitch Attitude

(C-GSLB, Flight 070, Terrace B.C.) (LP172/89)



Plotted: 27 DEC., 1990

APPENDIX F

LIST OF LABORATORY REPORTS

The following laboratory reports were completed:

LP 173/89 - Structures Group
LP 174/89 - Site Survey and Security Group
LP 177/89 - Documents Analysis
LP 178/89 - Systems Component Examination
LP 179/89 - Power Plant Examination
LP 182/89 - Engines Group
LP 194/89 - Instrument and Lightbulb Analysis
LP 201/89 - Site Survey
LP 225/89 - ELT Analysis
LP 023/90 - Stall Avoidance System

These reports are available from the Transportation Safety Board of Canada.

GLOSSARY

AD	Airworthiness Directive
AFM	Aircraft Flight Manual
agl	above ground level
AI	attitude indicator
AIP	Aeronautical Information Publication
ANO	Air Navigation Order
AOA	angle of attack
asl	above sea level
ATC	air traffic control
CAP	Canada Air Pilot
CAMU	Civil Aviation Medical Unit
CFR	Crash, Firefighting, and Rescue
CFS	Canada Flight Supplement
CO	carbon monoxide
C of A	Certificate of Airworthiness
C of G	centre of gravity
CRM	cockpit resource management
CVR	cockpit voice recorder
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FD	flight director
FDR	flight data recorder
FL	flight level
fpm	feet per minute
FRG	Federal Republic of Germany
FSS	flight service station
FT	terminal forecast
HCN	hydrogen cyanide
hr	hour(s)
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
lat	latitude
lb	pound(s)
LDA/DME	localizer type directional aid/distance measuring equipment
long	longitude
M	magnetic
MAP	missed approach point
MCM	Maintenance Control Manual
MDA	minimum descent altitudes

GLOSSARY

mg%	milligrams per cent
MTOW	maximum take-off weight
N	north
NDB	non-directional beacon
NOTAM	Notice to Airmen
OC	Operating Certificate
OM	Operations Manual
PA	public announcement
PDT	Pacific daylight time
PLH	Personnel Licensing Handbook
PPC	pilot proficiency check
rpm	rotations per minute
SAS	stall avoidance system
SB	Service Bulletin
SOPs	standard operating procedures
TC	Transport Canada
TSB	Transportation Safety Board
UTC	Coordinated Universal Time
V	airspeed
V_S	stall speed
VHF	very high frequency
VOR	very high frequency omni-directional range
W	west
°	degree(s)
'	minute(s)